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Special Number 3

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FOREWORD

The present issue constitutes the third special number of the "Records of Oceanographic Works in Japan", a pre-war scientific journal in European languages, which was revived in 1953 by this Commission and its regular publication is now being undertaken by the Science Council of Japan.

It contains reports on some of the results obtained during 1957 in connection with the oceanographic research projects of this Commission which were started in 1953 with the participation of many distinguished marine scientists in Japan.

It is hoped that together with the previous issues this number will prove useful to all those concerned with marine sciences abroad.

October 1959

Japanese National Commission
for Unesco

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A STUDY ON THE PRODUCTIVITY OF TANABE BAY
(Part II)
I. Tidal Currents in Tanabe Bay
(2nd Report)

By
Akikazu Nakamura
(Osaka University of Liberal Arts and Education)

I. PERIOD OF OBSERVATION. From 9th to 15th, August, 1957.

II. METHOD OF OBSERVATION. Both "drift-bottles" method and cup-type current meter method described in the Introductory Report* were adopted

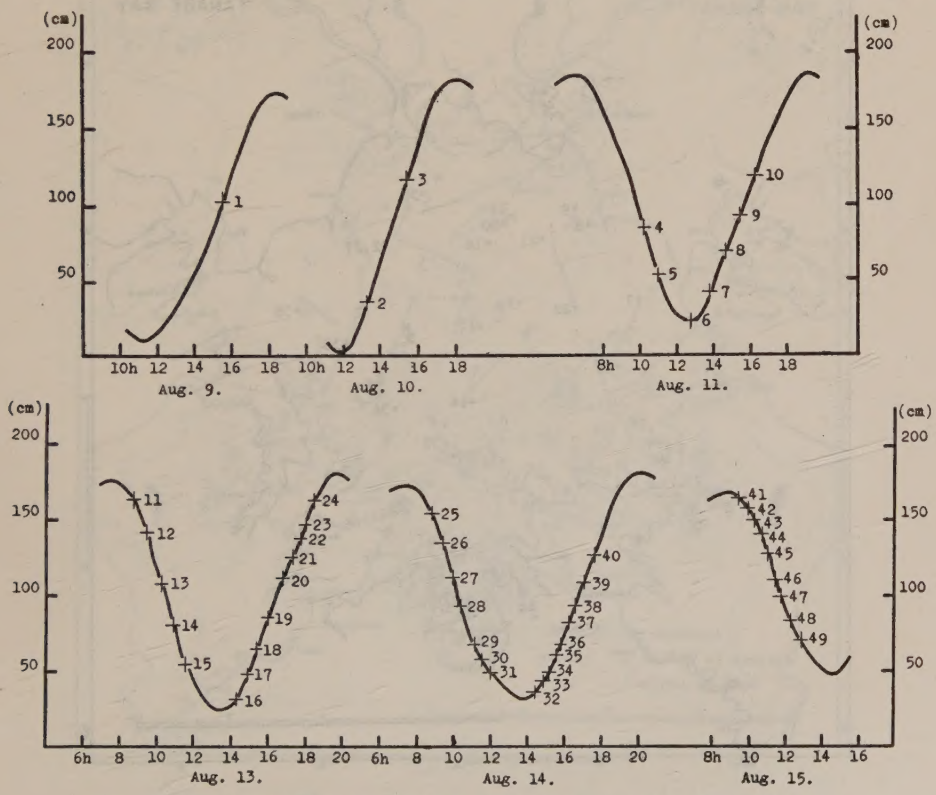

Fig. 1. Marigrams taken at Mori on Aug. 9~15. Crosses on the marigrams indicate the tidal phases of the stations.

* Records of Oceanographic Works in Japan, Special No. 2, P. 10~14, March, 1958.

again to collect information on the tidal currents of Tanabe Bay in the layer 6.0 meters in thickness. The latter method, by which the currents were measured chiefly to a depth of 3.0 m, was employed oftener to save time and trouble. The results obtained by these two methods at depths of 0.5, 1.0, 1.5 and 3.0 m, when compared, were found to be in fairly good agreement with each other at wind velocities below 5.0 m/sec.

The tides were observed by Prof. S. Hayami at Mori near the head of the bay, and the author was allowed to avail himself of the complete marigrams prepared. (Fig. 1.)

III. RESULTS OF OBSERVATION. Observations were made at 41 stations, as shown in Figs. 2 and 3. In Table 1 are given the results which in Figs. 4.a~4.f and 5.a~5.f are plotted in vector form.

In his previous report, the author described only the observed movements

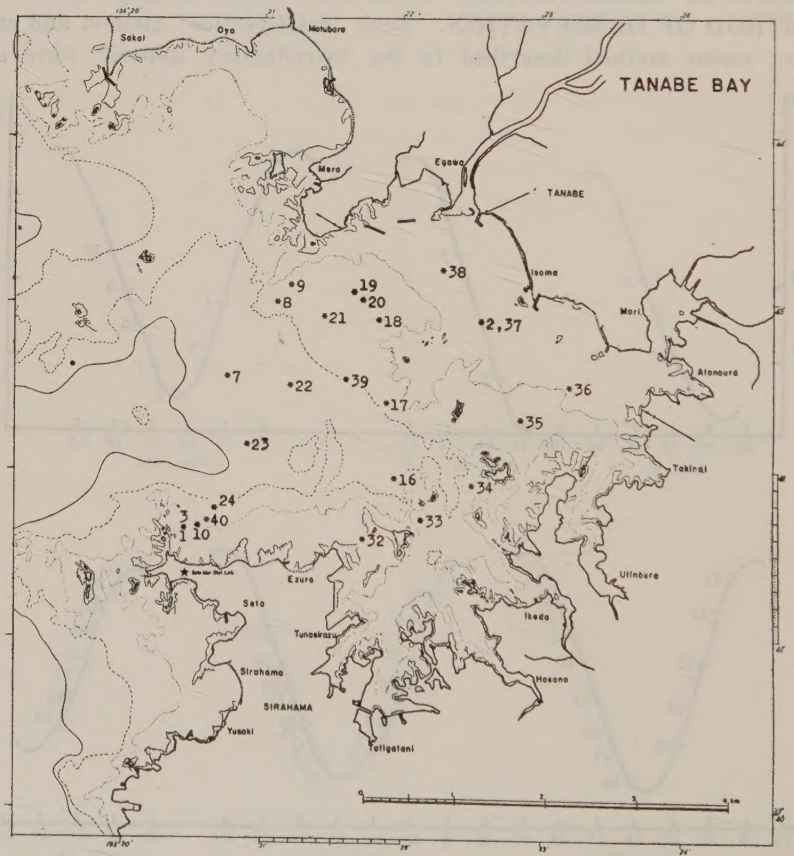

Fig. 2. Map showing the stations included under (A). Asterisks attached to numbers indicate the localities of the stations and a solid circle denotes the place of tide-gauge.

of drift-bottles, classifying them into seven categories with reference to the tidal phases at Mori: (1) near the low water phase, (2) the middle phase between low and high tides, (3) from the middle phase to the high water, (4) the high water and the phases close to it, (5) from the high water to the middle phase, (6) the middle phase between high and low tides and (7) from the middle phase to the low water. But this paper deals with the currents of the surface and subsurface layers of the bay in the two different tidal phases at Mori: (A) from the low water to the high, (B) from the high water to the low.

(A) From the low water to the high.

Fig. 2 shows the stations included under this head.

(1) The surface currents (Fig. 4.a). When the wind velocities are less than 5.0 m/sec, it appears that there is little drift of the surface water

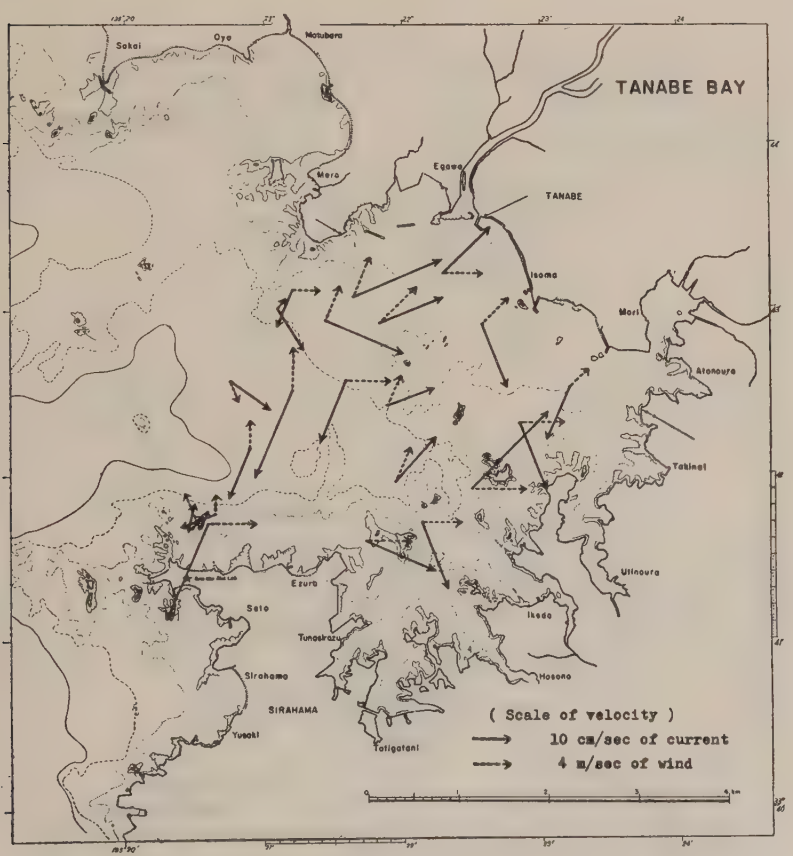

Fig. 4. a. The surface currents at the stations included under (A). A arrow shows the direction in which the current flows and a dotted one shows the direction in which the wind blows.

mass. The currents at the mouth of the bay show the southeasterly flows of 14~23 cm/sec in the northwardly part and the south-southwesterly ones of 15~29 cm/sec in the central and southern parts. Off the Seto Marine Biological Laboratory (Rinkai-ura), there exist two different flows of a slow northerly one of less than 10 cm/sec at Nos. 1 and 10 and a strong south-southwesterly one of 29 cm/sec at No. 40. A clockwise system of currents appears to prevail in the northern and eastern areas of the bay, and the currents in the central area are directed toward the south-southwest on the western side and toward the northeast on the eastern side. At the mouths of the branch bays in the southern area, there are inflows of 20 cm/sec or more into the inlets soon after the low water, though the current at No. 34, southwest of Kashima, runs in the north-eastern direction at the velocity of 30 cm/sec against the east wind of 5.7 m/sec.

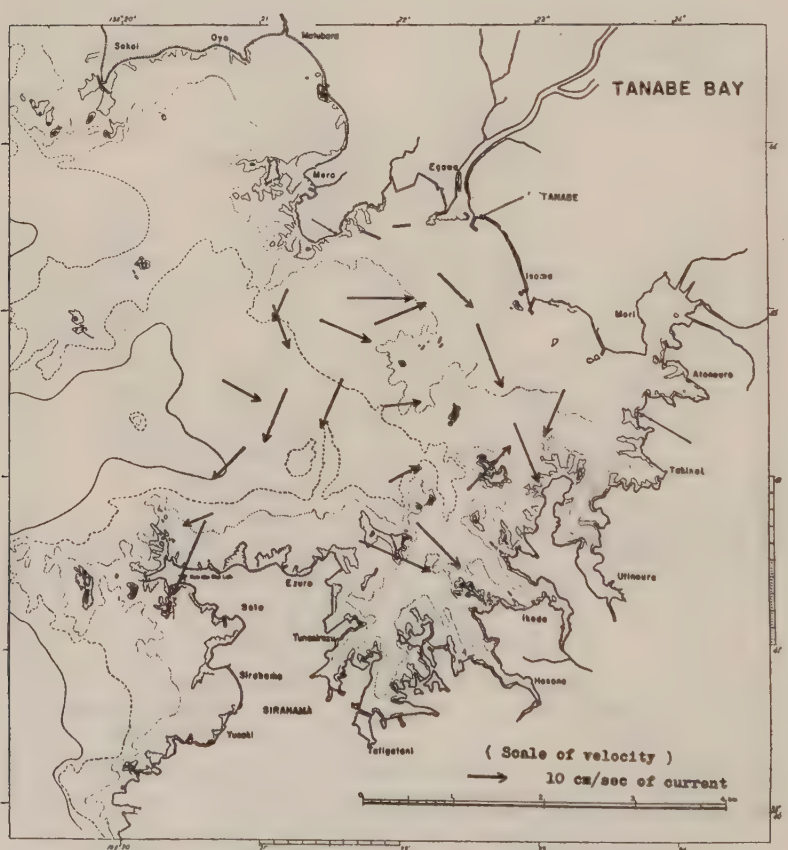

Fig. 4. b. The currents at a depth of 0.5 m at the stations included under (A).

(2) The subsurface currents (Figs. 4.b, 4.c, 4.d, 4.e and 4.f). At depths of 0.5, 1.0, 1.5 and 3.0 m, there exist almost the same currents as on the surface, but the current at No. 34 turns east or southeast at depths below 1.0 m, and the flows at No. 36 near the bay head and No. 40 in Rinkai-ura take the westward direction at depths below 1.5 m. At a depth of 6.0 m in the central and rather northwardly parts of the bay mouth, the currents run toward the south-southeast at the velocities of 12~17 cm/sec equal to or quicker than those in the upper layer, which suggests that the inflow through the layer below a depth of 6.0 m in these parts has much influence upon the flood tide of the Bay.

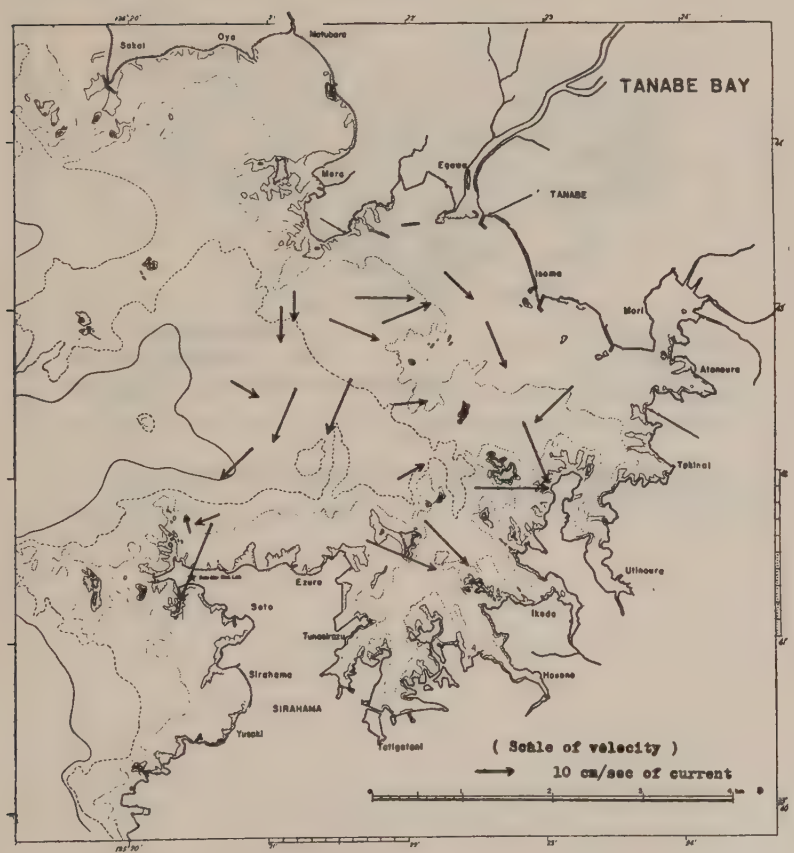

Fig. 4. c. The currents at a depth of 1.0 m at the stations included under (A).

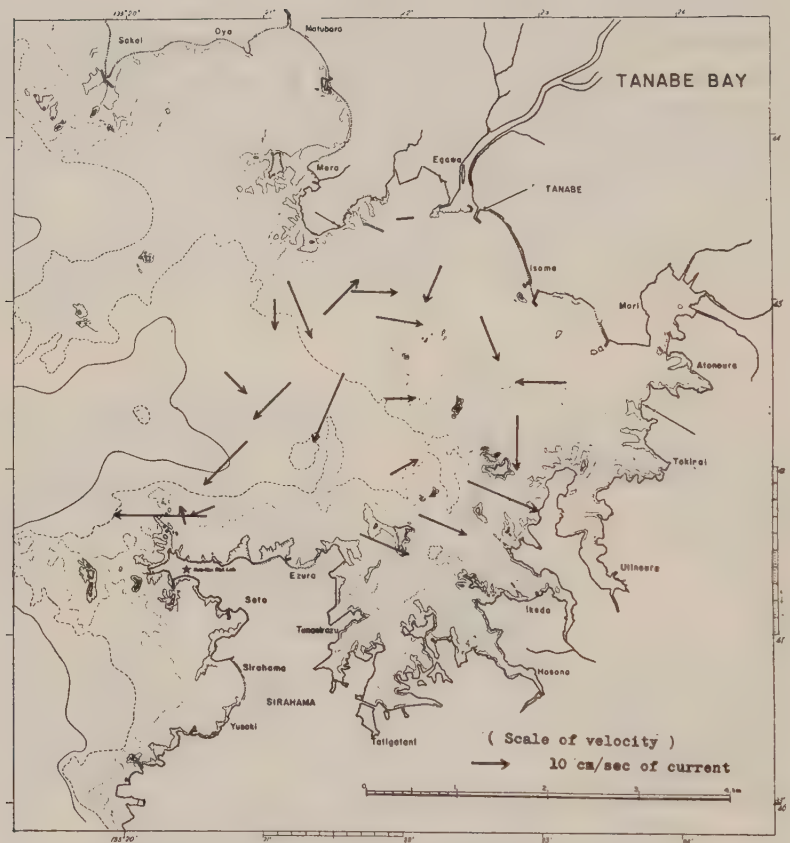

Fig. 4. d. The currents at a depth of 1.5 m at the stations included under (A).

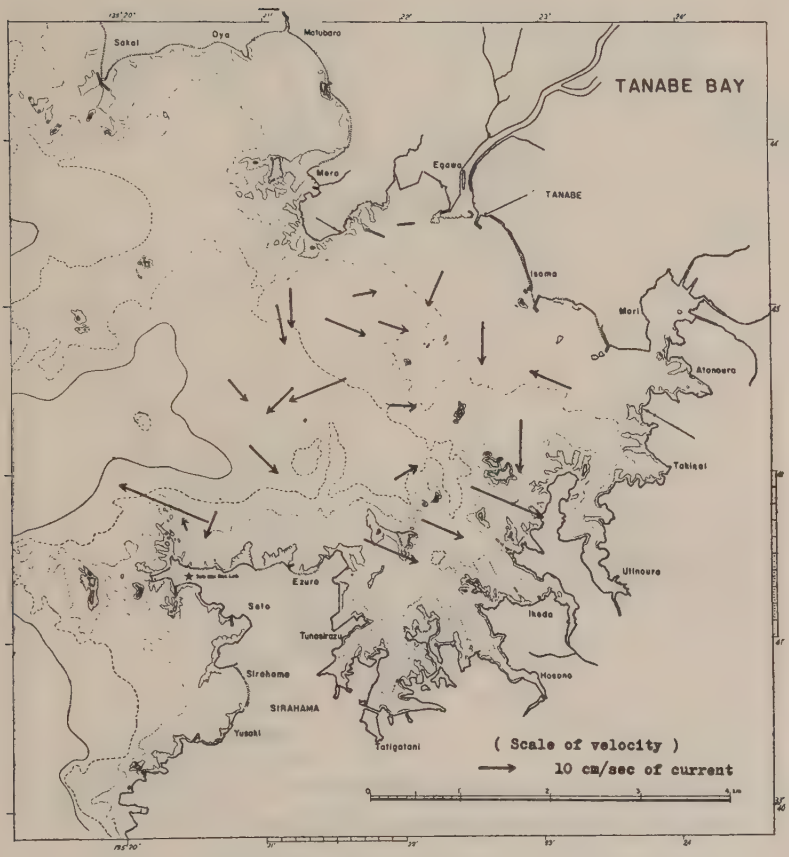

Fig. 4. e. The currents at a depth of 3.0 m at the stations included under (A).

Fig. 4. f. The currents at a depth of 6.0 m at the stations included under (A).

(B) From the high water to the low.

Fig. 3 shows the stations included under this head.

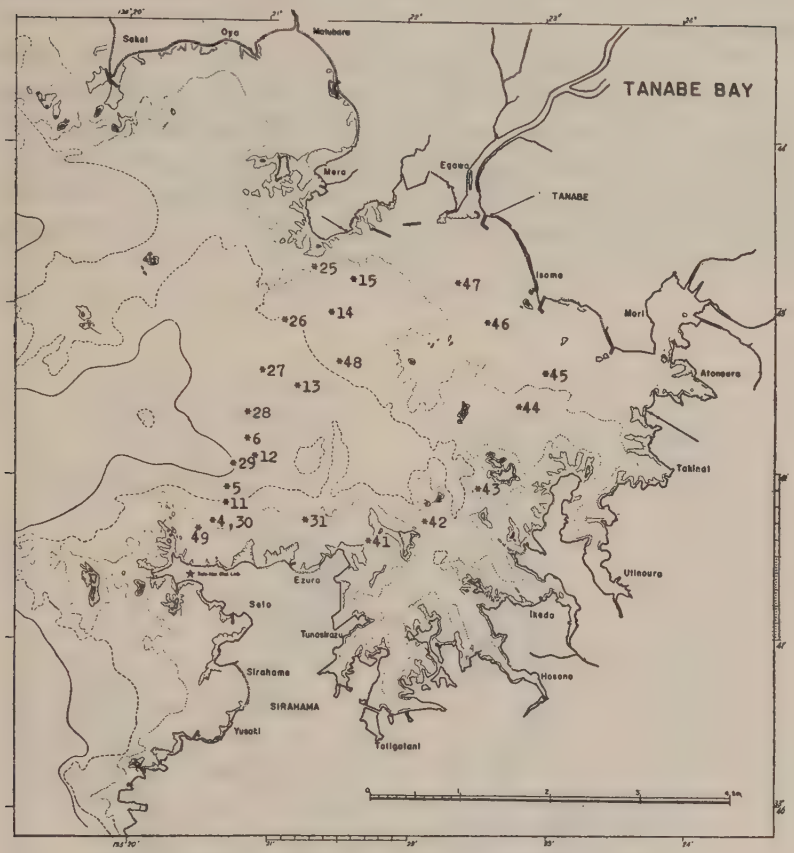

Fig. 3. Map showing the stations included under (B). Asterisks attached to numbers indicate the localities of the stations.

(1) The surface currents (Fig. 5.a). At the mouth of the bay, the northwesterly or west-northwesterly outflows except the southwesterly flow at No. 27 run at the velocities of 23~28 cm/sec in the central and rather northwardly parts, while there exist currents of various directions in the southern part.

The southerly and east-southeasterly currents of about 20 cm/sec in Rinkai-ura and off Ezura seem to form a system of currents against the outflow. In the eastern area of the bay, there appear to exist the northerly flows forming an anticlockwise system of currents. The current at No. 48, the only one station in the central area, flows toward the south-southeast at the velocity of 23 cm/sec against the south-southwest wind of over 4.4 m/sec.

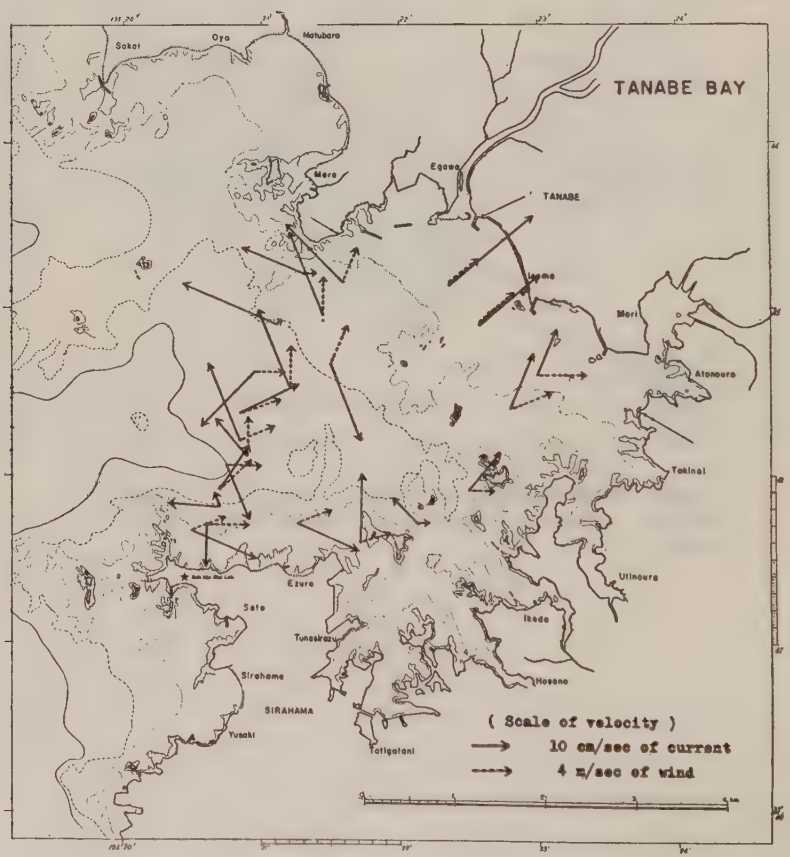

Fig. 5. a. The surface currents at the stations included under (B).

(2) The subsurface currents (Figs. 5.b, 5.c, 5.d, 5.e and 5.f). In the northern and eastern areas, an anticlockwise system of currents can be observed more clearly, according as the depth increases from 0.5 m to 3.0 m. The current at No. 48 turns from the south-southeast to the east-southeast at a depth of 0.5 m and inversely to the northwest at depths below 1.5 m, but its velocity at these depths remains to be about 18 cm/sec.

The central and rather northwardly parts of the bay mouth present the northwesterly or westerly currents of over 11 cm/sec at a depth of 6.0 m, showing thereby that the ebb tide of the bay depends mainly on the outflow in these parts. On the other hand, in the southern part, there are currents of various directions similar to those on the surface, and these currents show the influences due not only to the differences of tidal phases at the stations but also to the topography.

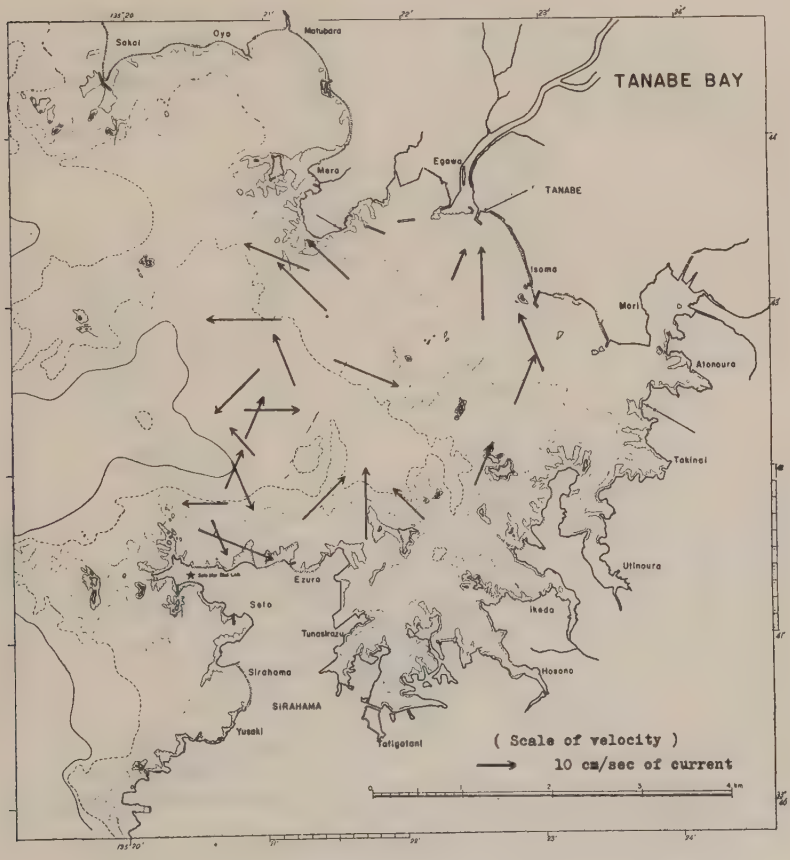

Fig. 5. b. The currents at a depth of 0.5 m at the stations included under (B).

The flow at No. 31 off Ezura changes its direction gradually from the east-southeast to the northeast at a depth of 0.5 m, to the northwest at 1.0 m, to the west-northwest at 1.5 m and to the west at 3.0 m, which suggests that the countercurrent from Rinkai-ura to off Ezura exists only at the depths above 0.5 m.

IV. CONCLUSION. It may be open to controversy to discuss the tidal currents of Tanabe Bay just under the two classified heads of (A) and (B), but the general trend of the currents can be outlined as follows.

1. The anticlockwise or clockwise system of currents during the ebb or flood respectively appears to prevail especially in the northern and eastern areas of the bay.
2. The tides in the bay depend mainly upon the movements of the water mass through the central and rather northwardly sections of the bay mouth,

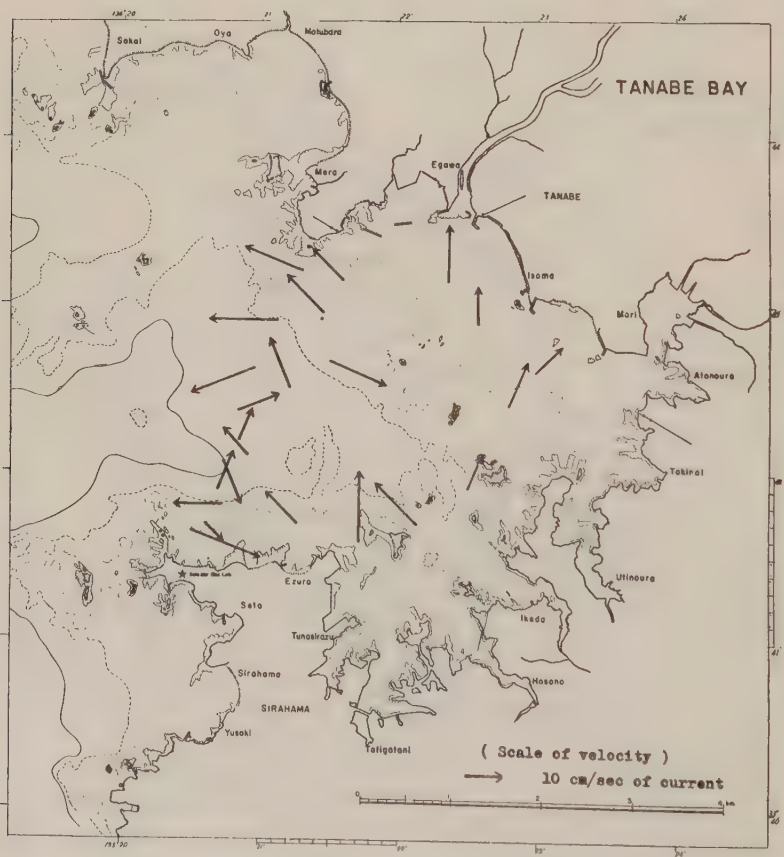

Fig. 5. c. The currents at a depth of 1.0 m at the stations included under (B).

and it may safely be supposed that the inflow through the layer below a depth of 6.0 m has much influence upon the flood tide.

3. Slow and complicated currents exist in the southern part of the bay mouth, owing chiefly to the topography, and they make less contribution to the tide in the bay.
4. The current off the Seto Marine Biological Laboratory appears to flow into or out of the bay during the ebb or flood respectively.
5. The movement of the water mass in the central area of the bay is complex, on account of the upwelling caused by the bottom topography.
6. The surface layer of about 1.5 m in thickness, in general, shows varied flows most frequently.

The present observations are still inadequate, as they are limited only to the upper layer. In order to gather more detailed and reliable information on

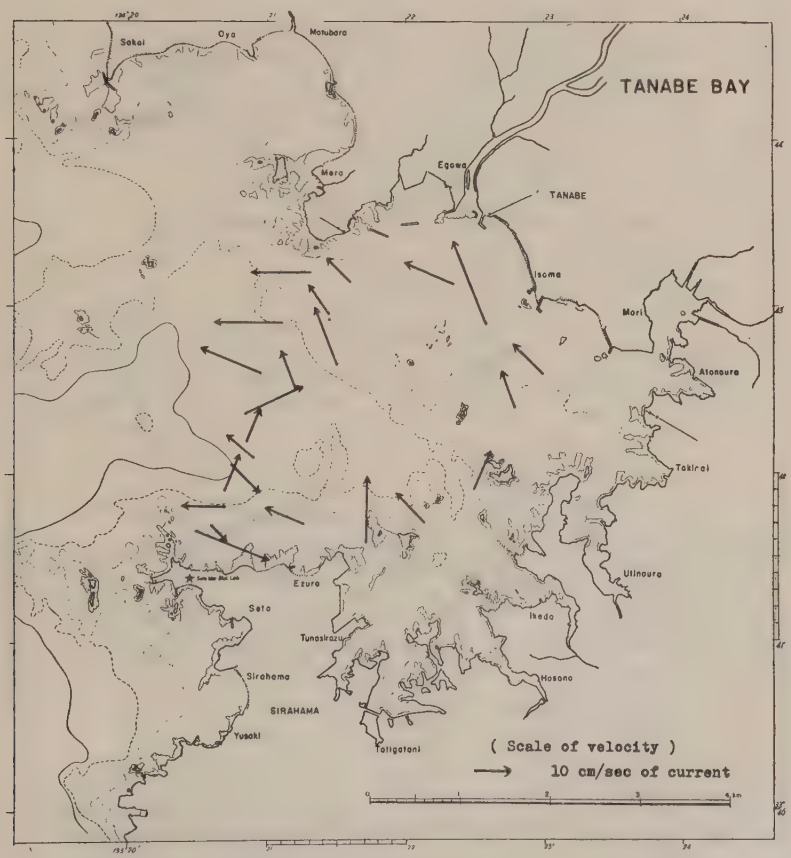

Fig. 5. d. The currents at a depth of 1.5 m at the stations included under (B).

the currents so complicated as those of Tanabe Bay, observations must be made from the surface down to the bottom, that is, both horizontally and vertically. The current meter available at present is of little use for this purpose. Some improved method of observation, which can save time, labour and money, must be worked out. It is the author's wish to attempt the observations of the deeper layers by such an improved method in the near future.

Acknowledgement

The author's thanks are due to Prof. Dr. D. Miyadi, Prof. Dr. S. Hayami, Dr. H. Utinomi and Dr. I. Yamazi for their kind guidance and encouragement in these investigations. His thanks are also due to Y. Watanabe, T. Hasegawa, T. Toyama and M. Nakagawa who assisted him in carrying out the observations.

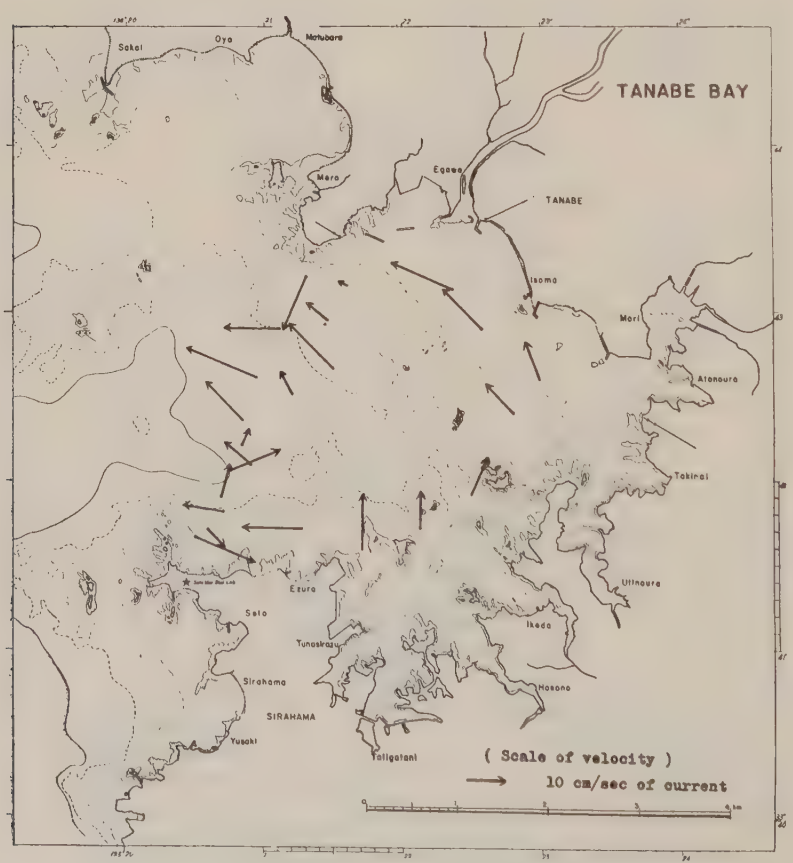

Fig. 5. e. The currents at a depth of 3.0 m at the stations included under (B).

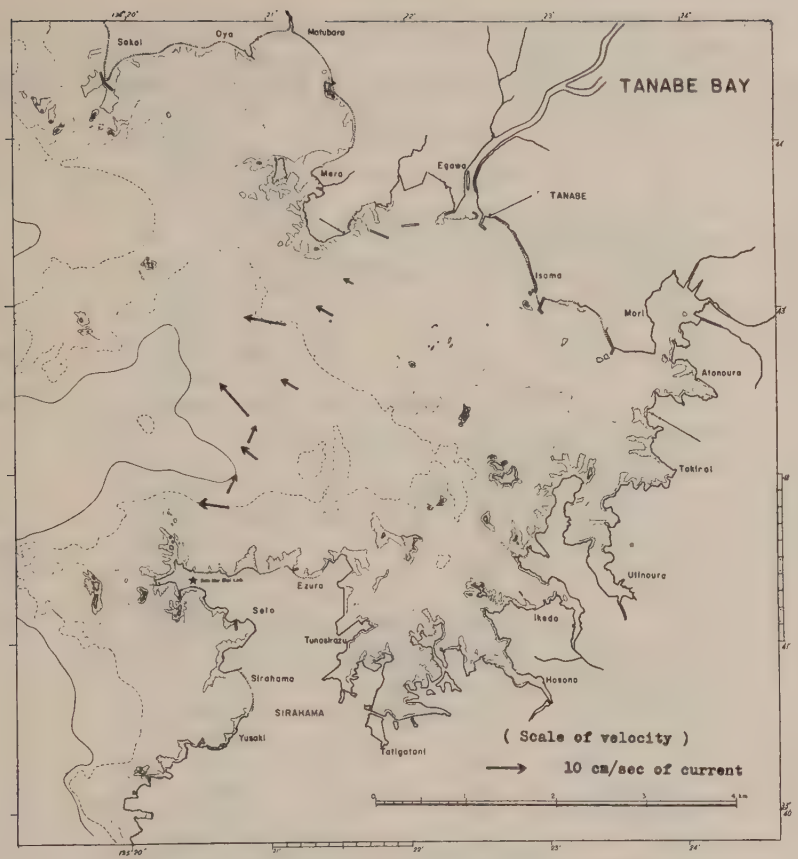

Fig. 5. f. The currents at a depth of 6.0 m at the stations included under (B).

Table Currents observed in Tanabe Bay (from 9th to 15th, August, 1957).

Station 1. From 15h15m to 16h09m (Mean: 15h42m), August 9.

Wind. SW 2.5 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	8 (cm/sec)	14° (NNE)	B*
1.0	5	344 (NNW)	B
1.5	5	344 (NNW)	B
3.0	3	338 (NNW)	B
6.0	3	332 (NNW)	B

Station 2. From 13h00m to 13h40m (13h20m), Aug. 10.

Wind. WSW 4.4 (m/sec)

0 (m)	3 (cm/sec)	79° (E)	B
1.0	3	99 (E)	B
1.5	2	119 (ESE)	B
3.0	3	17 (NNE)	B

Station 3. From 15h30m to 15h40m (15h35m), Aug. 10.
Wind. S 2.4 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	—	—	—
0.5	35 (cm/sec)	NNE	P**
1.0	6	20° (NNE)	B
1·5	0	—	P,B

Station 4. From 09h50m to 10h32m (10h11m), Aug. 11.
Wind. WNW 2.9 (m/sec)

0 (m)	7 (cm/sec)	61° (NE)	B
0.5	5	52 (NE)	B
1.0	3	36 (NE)	B
1.5	3	36 (NE)	B
3.0	3	37 (NE)	B
6.0	2	339 (NNW)	B

Station 5. From 10h42m to 11h17m (11h00m), Aug. 11.
Wind. SW 4.7 (m/sec)

0 (m)	15 (cm/sec)	33° (NNE)	B,P
0.5	12	24 (NNE)	B,P
1.0	11	22 (NNE)	B,P
1.5	11	22 (NNE)	B,P
3.0	8	15 (NNE)	B,P
6.0	5	25 (NNE)	B

Station 6. From 12h31m to 12h53m (12h42m), Aug. 11.
Wind. WSW 4.0 (m/sec)

0 (m)	24 (cm/sec)	NNW	P
0.5	12	NNE	P
1.0	9	NNE	P
1.5	11	NNE	P
3.0	5	22° (NNE)	B
6.0	5	22° (NNE)	B

Station 7. From 13h34m to 14h07m (13h50m), Aug. 11.
Wind. NNW 2.6 (m/sec)

0 (m)	14 (cm/sec)	124° (ESE)	B,P
0.5	12	118 (ESE)	B,P
1.0	9	121 (ESE)	B,P
1.5	8	135 (SE)	B,P
3.0	8	141 (SE)	B
6.0	12	155 (SSE)	B

Station 8. From 14h30m to 14h57m (14h43m), Aug. 11.
Wind. NW 1.0 (m/sec)

0 (m)	14 (cm/sec)	147° (SSE)	B,P
0.5	12	159 (SSE)	B,P
1.0	10	180 (S)	B,P
1.5	8	181 (S)	B,P
3.0	11	170 (S)	B,P
6.0	17	165 (SSE)	B

Station 9. From 15h09m to 15h35m (15h22m), Aug. 11.
Wind. W 3.0 (m/sec)

0 (m)	11 (cm/sec)	SSW	P
0.5	9	SSW	P
1.0	8	180° (S)	B,P
1.5	17	160 (SSE)	B,P
3.0	11	180 (S)	B,P
6.0	9	180 (S)	B

Station 10. From 16h07m to 16h18m (16h12m), Aug. 11.
Wind. SSE 4.7 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	5 (cm/sec)	20° (NNE)	B
0.5~6.0	0	—	B

Station 11. From 08h35m to 09h03m (08h49m), Aug. 13.
Wind. SSE 3.5 (m/sec)

0 (m)	14 (cm/sec)	273° (W)	B,P
0.5	12	270 (W)	B,P
1.0	12	270 (W)	B,P
1.5	12	272 (W)	B,P
3.0	11	278 (W)	B,P
6.0	8	278 (W)	B

Station 12. From 09h14m to 09h46m (09h30m), Aug. 13.
Wind. S 4.5 (m/sec)

0 (m)	14 (cm/sec)	320° (NW)	B,P
0.5	10	318 (NW)	B,P
1.0	10	318 (NW)	B,P
1.5	9	310 (NW)	B,P
3.0	9	309 (NW)	B,P
6.0	5	309 (NW)	B

Station 13. From 10h00m to 10h23m (10h11m), Aug. 13.
Wind. S 4.6 (m/sec)

0 (m)	23 (cm/sec)	NNW	P
0.5	15	NNW	P
1.0	14	NNW	P
1.5	11	NNW	P
3.0	7	330° (NNW)	B
6.0	5	300° (NNW)	B

Station 14. From 10h42m to 11h09m (10h55m), Aug. 13.
Wind. S 4.4 (m/sec)

0 (m)	26 (cm/sec)	NNW	P
0.5	19	NW	P
1.0	14	NW	P
1.5	10	324° (NW)	B,P
3.0	7	310 (NW)	B
6.0	4	300 (WNW)	B

Station 15. From 11h21m to 11h38m (11h29m), Aug. 13.
Wind. SSW 4.0 (m/sec)

0 (m)	23 (cm/sec)	NW	P
0.5	16	NW	P
1.0	13	NW	P
1.5	9	NW	P
3.0	2	300° (WNW)	B
6.0	2	300 (WNW)	B

Station 16. From 14h00m to 14h28m (14h14m), Aug. 13.
Wind. SSW 4.5 (m/sec)

0 (m)	17 (cm/sec)	40° (NE)	B,P
0.5	9	60 (ENE)	B,P
1.0	8	60 (ENE)	B,P
1.5	8	60 (ENE)	B,P
3.0	7	60 (ENE)	B
6.0	6	60 (ENE)	B

Station 17. From 14h40m to 15h09m (14h54m), Aug. 13.
Wind. SSW 3.8 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	14 (cm/sec)	68° (ENE)	B,P
0.5	10	83 (E)	B,P
1.0	10	83 (E)	B,P
1.5	8	90 (E)	B,P
3.0	7	94 (E)	B
6.0	4	107 (ESE)	B

Station 18. From 15h19m to 15h43m (15h31m), Aug. 13.
Wind. SW 5.1 (m/sec)

0 (m)	19 (cm/sec)	70° (ENE)	B,P
0.5	15	70 (ENE)	B,P
1.0	13	73 (ENE)	B,P
1.5	13	100 (ESE)	B,P
3.0	8	110 (ESE)	B,P
6.0	5	110 (ESE)	B

Station 19. From 15h53m to 16h18m (16h05m), Aug. 13.
Wind. SSW 5.0 (m/sec)

0 (m)	27 (cm/sec)	75° (ENE)	B,P
0.5	18	85 (E)	B,P
1.0	16	85 (E)	B,P
1.5	13	85 (E)	B,P
3.0	6	80 (E)	B
6.0	6	60 (ENE)	B

Station 20. From 16h32m to 16h57m (16h44m), Aug. 13.
Wind. SSW 5.4 (m/sec)

0 (m)	22 (cm/sec)	SE	P
0.5	18	SE	P
1.0	20	SE	P
1.5	20	SE	P
3.0	10	SE	P

Station 21. From 17h15m to 17h20m (17h17m), Aug. 13.
Wind. SSW 4.2 (m/sec)

0 (m)	23 (cm/sec)	ESE	P
0.5	15	ESE	P
1.0	15	ESE	P
1.5	13	NE	P
3.0	12	ESE	P

Station 22. From 17h36m to 17h46m (17h41m), Aug. 13.
Wind. S 4.5 (m/sec)

0 (m)	27 (cm/sec)	SSW	P
0.5	16	SSW	P
1.0	16	SSW	P
1.5	14	SW	P
3.0	10	SW	P

Station 23. From 18h01m to 18h09m (18h05m), Aug. 13.
Wind. S 3.1 (m/sec)

0 (m)	15 (cm/sec)	SSW	P
0.5	12	SW	P
1.0	12	SW	P
1.5	17	SW	P
3.0	11	SE	P

Station 24. From 18h22m to 18h36m (18h29m), Aug. 13.
Wind. S 1.8 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	10 (cm/sec)	WSW	P
0.5	8	WSW	P
1.0	7	WSW	P
1.5	7	WSW	P
3.0	8	SSW	P

Station 25. From 08h43m to 08h53m (08h48m), Aug. 14.
Wind. W 1.4 (m/sec)

0 (m)	19 (cm/sec)	WNW	P
0.5	19	WNW	P
1.0	17	WNW	P
1.5	16	W	P
3.0	16	SSW	P

Station 26. From 09h10m to 09h33m (09h21m), Aug. 14.
Wind. WSW 0.5 (m/sec)

0 (m)	28 (cm/sec)	WNW	P
0.5	21	W	P
1.0	19	W	P
1.5	19	W	P
3.0	15	W	P
6.0	11	280° (W)	B

Station 27. From 09h46m to 09h56m (09h51m), Aug. 14.
Wind. W 3.5 (m/sec)

0 (m)	21 (cm/sec)	SW	P
0.5	18	SW	P
1.0	19	WSW	P
1.5	18	WNW	P
3.0	21	WNW	P

Station 28. From 10h05m to 10h40m (10h22m), Aug. 14.
Wind. WSW 4.1 (m/sec)

0 (m)	18 (cm/sec)	62° (ENE)	B,P
0.5	15	90 (E)	B,P
1.0	12	64 (ENE)	B,P
1.5	16	64 (ENE)	B,P
2.0	15	N	P
3.0	14	310 (NW)	B,P
6.0	11	318 (NW)	B

Station 29. From 11h00m to 11h20m (11h10m), Aug. 14.
Wind. W 4.0 (m/sec)

0 (m)	16 (cm/sec)	SSE	P
0.5	14	SSE	P
1.0	12	SSE	P
1.5	11	SE	P
2.0	14	ENE	P
3.0	15	ENE	P

Station 30. From 11h30m to 11h38m (11h34m), Aug. 14.
Wind. W 5.0 (m/sec)

0 (m)	12 (cm/sec)	S	P
0.5	10	SSE	P
1.0	8	SE	P
1.5	7	SE	P
3.0	7	SE	P

Station 31. From 11h50m to 11h59m (11h55m), Aug. 14.
Wind. WSW 4.0 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	19 (cm/sec)	ESE	P
0.5	17	NE	P
1.0	12	NW	P
1.5	11	WNW	P
3.0	16	W	P

Station 32. From 14h14m to 14h26m (14h20m), Aug. 14.
Wind. W 4.7 (m/sec)

0 (m)	22 (cm/sec)	ESE	P
0.5	21	ESE	P
1.0	21	ESE	P
1.5	14	ESE	P
2.0	15	ESE	P
3.0	16	ESE	P

Station 33. From 14h41m to 14h50m (14h45m), Aug. 14.
Wind. W 4.1 (m/sec)

0 (m)	20 (cm/sec)	SSE	P
0.5	17	SE	P
1.0	17	SE	P
1.5	14	ESE	P
3.0	12	ESE	P

Station 34. From 15h00m to 15h05m (15h03m), Aug. 14.
Wind. W 5.7 (m/sec)

0 (m)	30 (cm/sec)	NE	P
0.5	17	NE	P
1.0	20	E	P
1.5	21	ESE	P
3.0	21	ESE	P

Station 35. From 15h22m to 15h28m (15h25m), Aug. 14.
Wind. W 5.0 (m/sec)

0 (m)	20 (cm/sec)	SSE	P
0.5	18	SSE	P
1.0	18	SSE	P
1.5	15	S	P
3.0	15	S	P

Station 36. From 15h41m to 15h50m (15h45m), Aug. 14.
Wind. SW 3.3 (m/sec)

0 (m)	16 (cm/sec)	SSW	P
0.5	15	SSW	P
1.0	14	SW	P
1.5	14	W	P
3.0	11	WNW	P

Station 37. From 16h09m to 16h16m (16h12m), Aug. 14.
Wind. SW 4.1 (m/sec)

0 (m)	19 (cm/sec)	SSE	P
0.5	19	SSE	P
1.0	14	SSE	P
1.5	13	SSE	P
3.0	12	S	P

Station 38. From 16h26m to 16h38m (16h32m), Aug. 14.
Wind. W 4.4 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	18 (cm/sec)	NE	P
0.5	14	SE	P
1.0	11	SE	P
1.5	11	SSW	P
3.0	11	SSW	P

Station 39. From 16h58m to 17h06m (17h02m), Aug. 14.
Wind. W 5.1 (m/sec)

0 (m)	18 (cm/sec)	SSW	P
0.5	14	SSW	P
1.0	16	SSW	P
1.5	21	SSW	P
2.0	21	SSW	P
3.0	17	WSW	P

Station 40. From 17h30m to 17h39m (17h34m), Aug. 14.
Wind. W 5.4 (m/sec)

0 (m)	29 (cm/sec)	SSW	P
0.5	22	SSW	P
1.0	24	SSW	P
1.5	27	W	P
3.0	27	WNW	P

Station 41. From 09h35m to 09h40m (09h37m), Aug. 15.
Wind. WSW 3.3 (m/sec)

0 (m)	19 (cm/sec)	N	P
0.5	20	N	P
1.0	20	N	P
1.5	18	N	P
3.0	15	N	P

Station 42. From 10h00m to 10h08m (10h04m), Aug. 15.
Wind. W 1.0 (m/sec)

0 (m)	10 (cm/sec)	NW	P
0.5	12	NW	P
1.0	16	NW	P
1.5	11	NW	P
3.0	10	N	P

Station 43. From 10h18m to 10h26m (10h22m), Aug. 15.
Wind. W 2.7 (m/sec)

0 (m)	14 (cm/sec)	NE	P
0.5	13	NNE	P
1.0	11	NNE	P
1.5	12	NNE	P
3.0	12	NNE	P

Station 44. From 10h42m to 10h55m (10h48m), Aug. 15.
Wind. WSW 4.5 (m/sec)

0 (m)	17 (cm/sec)	NNE	P
0.5	15	NNE	P
1.0	13	NNE	P
1.5	11	NNW	P
3.0	11	NW	P

Station 45. From 11h06m to 11h14m (11h10m), Aug. 15.
Wind. W 5.2 (m/sec)

(Depth)	(Current velocity)	(Current direction)	(Method)
0 (m)	14 (cm/sec)	NNW	P
0.5	17	NNW	P
1.0	10	NW	P
1.5	12	NW	P
3.0	11	NNW	P

Station 46. From 11h30m to 11h35m (11h32m), Aug. 15.
Wind. SW 5.3 (m/sec)

0 (m)	21 (cm/sec)	NE	P
0.5	20	N	P
1.0	21	N	P
1.5	25	NNW	P
3.0	16	NW	P

Station 47. From 11h47m to 11h55m (11h51m), Aug. 15.
Wind. SW 4.4 (m/sec)

0 (m)	30 (cm/sec)	NE	P
0.5	9	NNE	P
1.0	16	N	P
1.5	15	WNW	P
3.0	18	WNW	P

Station 48. From 12h14m to 12h30m (12h22m), Aug. 15.
Wind. SSW 4.4 (m/sec)

0 (m)	23 (cm/sec)	SSE	P
0.5	19	ESE	P
1.0	17	ESE	P
1.5	17	NNW	P
2.0	18	NW	P
3.0	18	NW	P

Station 49. From 12h51m to 12h56m (12h53m), Aug. 15.
Wind. WSW 3.9 (m/sec)

0 (m)	19 (cm/sec)	ESE	P
0.5	22	ESE	P
1.0	21	ESE	P
1.5	21	ESE	P
3.0	18	ESE	P

(Note) * , ** : B and P stand for drift-bottles and cup-type current meter respectively.

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A STUDY ON THE PRODUCTIVITY OF TANABE BAY
(Part II)

II. On Some Plankton Indicating the Water Exchange in Tanabe Bay in August, 1957

By
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(Seto Marine Biological Laboratory, Kyoto University)

This paper deals with the result of the second survey in Tanabe Bay made on August 6 and 7, 1957. The object and method of the survey are the same as the former work (YAMAZI, 1958). Plankton samples were collected simultaneously with the survey of the current made by Mr. Nakamura.

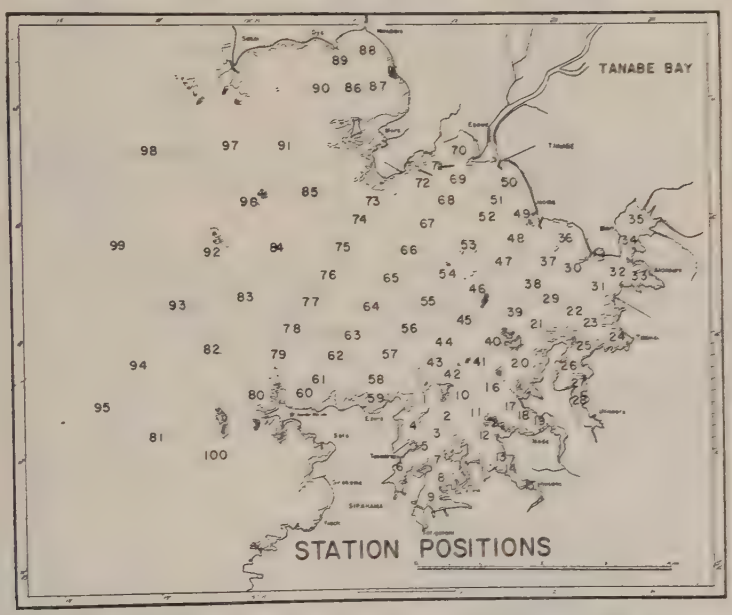

Fig. 1. Map of Tanabe Bay showing the stations surveyed on August 6 and 7, 1957.

Result of Observation

Plankton volume per 5 meter hauls (measured by settling volume) is shown for comparison in Fig. 2, including both zoo- and phytoplankton. The volume was, on the whole, small throughout all stations. The largest volume was found

Fig. 2. Settling volume of plankton per 5 m hauls at each station.

Fig. 3. Total number of zooplankton per 5 m hauls at each station.

Fig. 4. Distribution of copepods *Acartia* spp. per 5 m hauls.

Fig. 5. Distribution of copepod *Oithona nana* per 5 m hauls.

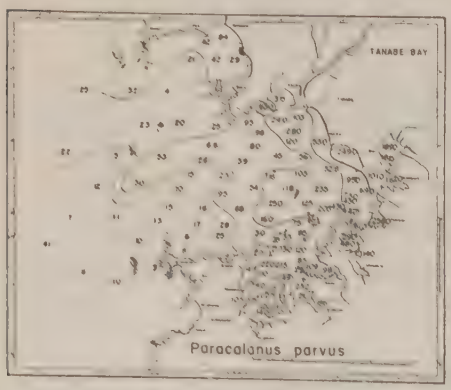

Fig. 6. Distribution of copepod *Paracalanus parvus* per 5 m hauls.

Fig. 7. Distribution of Cladocera *Penilia schmackeri* per 5 m hauls.

in the inner part, especially in the arms of the bay. There was also found a tongue-like extension of dense population towards the center from the inner baylet (Fig. 2).

Total number of zooplankton population per 5 meter hauls was the largest in five arms and around the northeastern area of the bay. The population decreased towards the entrance and along the northern and southern coasts (Fig. 3). As the plankton composition differed from area to area, the distribution of volume and number was not parallel at each station.

Copepods were the major constituents of zooplankton and followed by cladocerans, tunicates and chaetognaths. Among the local autogenetic organisms were copepods *Acartia erythraea, A. clausi, Oithona nana, Paracalanus parvus* and their nauplii, *Microsetella rosea,* tunicate *Oikopleura dioica,* chaetognath *Sagitta delicata,* cladoceran *Penilia schmackeri,* pelecypod and gastropod veligers. Oceanic and coastal allogenetic forms were represented by oceanic chaetognaths and appendicularians, copepods *Oithona similis, Oncaea* spp. and *Corycaeus* spp. etc. They showed also a characteristic distribution in the bay.

Acartia erythraea and *A. clausi:* *A. erythraea* is a littoral and brackish-water form which is abundant in warm season from early summer to early winter. *A. clausi* is, on the contrary, a cold-water form abundant from winter to early summer. The distribution area of both species in an inlet is quite similar, though their seasonal occurrences differ (YAMAZI, 1956). In this survey these species were found to thrive together in the inner part of the bay as well as near the northeastern coast and southeastern inlet (Fig. 4). The nauplii and copepodids of *Acartia erythraea* occurred densely at the inner stations and dispersed towards the mouth.

Oithona nana and *Paracalanus parvus*: These small littoral copepods were most abundant in the bay. They occurred densely in the area inside the line connecting Egawa on the northern coast and Ezura on the southern coast. The largest population was found in five arms of the bay. There was also a tongue-like extension of dense population towards the center of the bay. At the same time extensions toward the entrance of the bay on the northern and southern coasts were also found although their population was relatively small (Figs. 5 and 6).

Penilia schmackeri: This cladoceran which did not appear during the previous survey is also an important constituent during the early summer (YAMAZI, 1956). The greatest concentration was found in the area inside the line connecting Isoma and Ezura, where the water is rather stagnant and of lower salinity, but a small number was also found in the outer part of the bay (Fig. 7).

Microsetella rosea: This species was widely distributed in the bay, though in very small numbers in the inner and outer part of the bay. The densest population was found in the center of the bay to extend southwards. (Fig. 8).

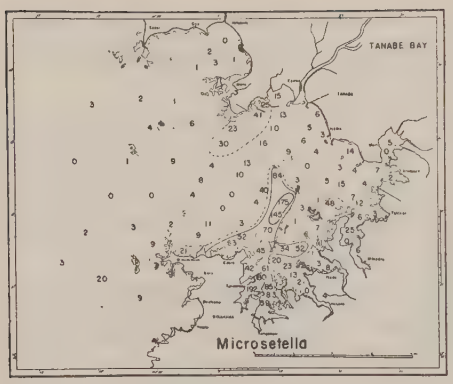

Fig. 8. Distribution of copepod *Microsetella rosea* per 5 m hauls.

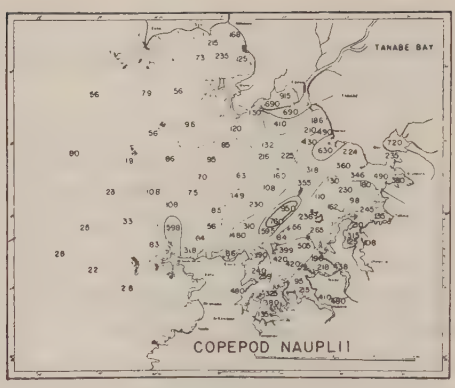

Fig. 9. Distribution of copepod nauplii per 5 m hauls.

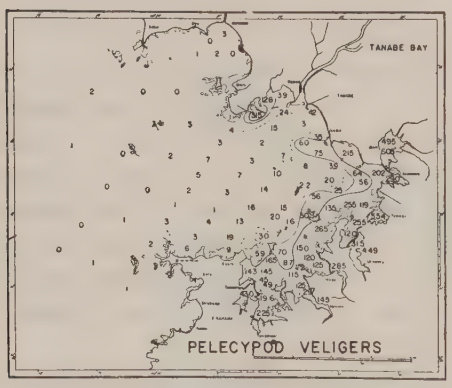

Fig. 10. Distribution of pelecypod veligers per 5 m hauls.

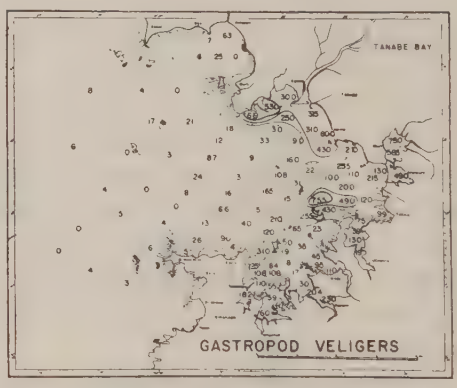

Fig. 11. Distribution of gastropod veligers per 5 m hauls.

Fig. 12. Distribution of chaetognath *Sagitta delicata* per 5 m hauls.

Fig. 13. Distribution of tunicate *Oikopleura dioica*. The number indicates per 5 m hauls.

Larval plankton: Among the larval plankton groups with characteristic distribution were copepod nauplii, gastropod and pelecypod veligers. The specific identification of these larvae was not made, although they were the important constituents of the plankton of the bay. Copepod nauplii were widely and abundantly distributed in the inner area and along the northern coast near Tanabe City. Gastropod and pelecypod veligers showed similar distribution (Figs. 9–11).

Sagitta delicata: The only important littoral chaetognath *Sagitta delicata* occurred more abundantly in the inner area, especially in five arms. The dense population was found off Kasima as a tongue-like extension and off Ezura on the southern coast (Fig. 12).

Oikopleura dioica: This is the only littoral form of Copelata. It was restricted numerically in the inner area inside the line connecting Tanabe City and Ezura. In the outer area near the mouth it was absent or very scanty. Its distribution resembled somewhat that of *Sagitta delicata* (Fig. 13).

Oithona similis, Oncaea and *Corycaeus:* A small copepod *Oithona similis* occurred more widely in the outer area than the foregoing plankton animals, but disappeared in the inner part of the bay. A small number was found near the center of the bay and along the northern coast. *Oncaea* and *Corycaeus* were also found near the entrance and towards the center of the bay (Figs. 14 and 15).

The distribution of other important oceanic components, such as chaetognaths, tunicates and copepods are shown in Figs. 16, 17 and 18.

Discussion and Conclusion

From the results of two plankton surveys in 1956 and 1957, the distribution of plankton was found to be closely correlated with the hydrographical conditions. The bay can be divided into four areas, each area having its characteristic community and productivity, as was shown in my former report (YAMAZI, 1958).

The stagnant inner water favors the development of dense zoo- and phytoplankton communities which are composed chiefly of smaller organisms as compared with oceanic and neritic forms (YAMAZI, 1956). This is a very important problem with regard to the food chain of higher forms in inlet waters. The greatest productivity of plankton-feeding animals such as benthic animals and juvenile fishes are found in coastal or inlet waters. In Tanabe Bay the plankton-feeding adult fishes are scarce at any time, but filter-feeding benthic animals, which are well suited to utilize the small planktons, are found everywhere in a high concentration. The juvenile fishes such as sardin, kibinago (*Sterephorus japonica*), pampano and ayu (*Plecoglossus altivelis*) also come into the bay and stay there during their early stages of development. The small zooplankton organisms in the bay may furnish food for these species.

Some of the inlet-water forms forming dense populations in the inner area and narrow arms are dispersed toward the entrance of the bay along the southern coast, northern shore and central area where they form tongue-like extension.

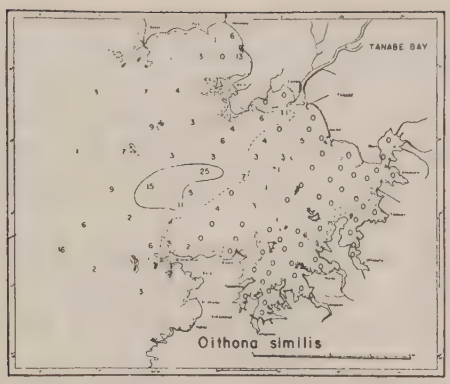

Fig. 14. Distribution of copepod *Oithona similis* per 5 m hauls.

Fig. 15. Distribution of *Oncaea* and *Corycaeus* per 5 m hauls.

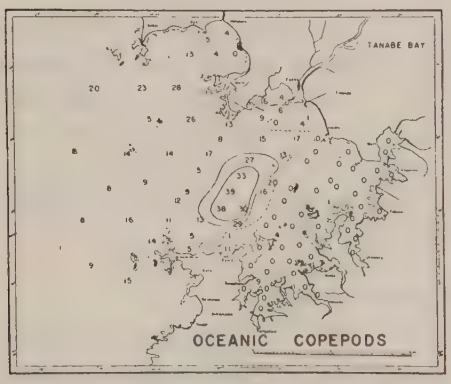

Fig. 16. Distribution of oceanic copepods per 5 m hauls.

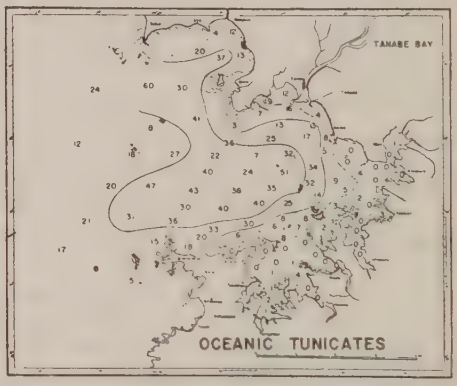

Fig. 17. Distribution of oceanic tunicates per 5 m hauls.

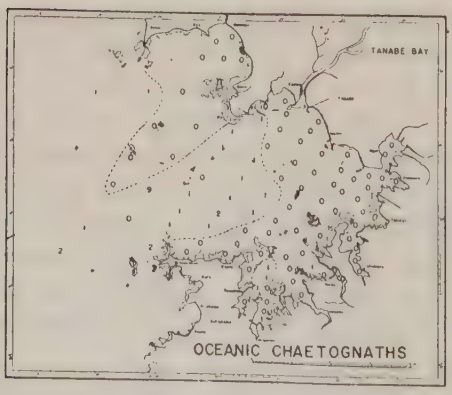

Fig. 18. Distribution of oceanic chaetognaths per 5 m hauls.

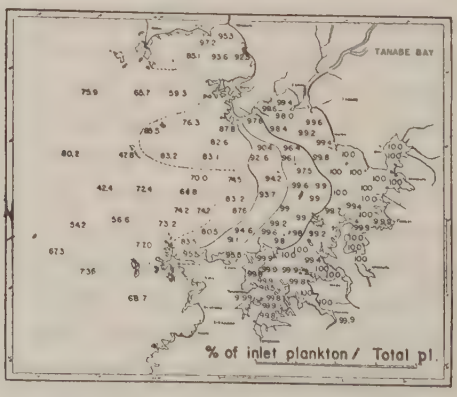

Fig. 19. Distributional map of percentage composition of local forms per total plankton animals.

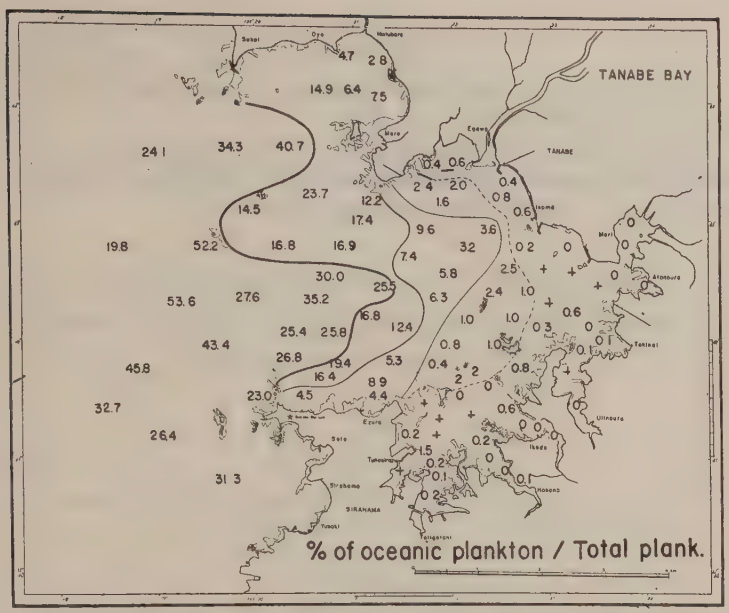

Fig. 20. Distributional map of percentage composition of the allogenetic population per total plankton animals.

This is illustrated by the extension of local plankton including *Oithona, Paracalanus, Acartia, Sagitta delicata, Oikopleura dioica, Penilia schmackeri* and larval forms, although the population in these dispersed areas is far smaller than that of the inner areas. The same tendency was reported in my former paper.

The invasions of the open-sea forms are shown in Figs. 14–20. These organisms which occur abundantly outside the bay flow into the central areas of the bay and extend to the northeastern areas often beyond an islet Hatake-zima. In northern baylets the population of open-sea forms is very small. It shows that the influx of the oceanic waters is not so strong as to influence the conditions of the baylet waters.

The percentage compositions of both the inlet-water and open-sea forms are given in Figs. 19 and 20. By the comparison of the distribution of the percentage composition and the population of these two forms in July, 1957 with that in November, 1956, the value for the former is found smaller than that of the latter, the fact suggesting that the oceanic influx in July, 1957 was weaker than that in November, 1956.

As described above and in my previous report (YAMAZI, 1958), the plankton in inlet waters is used as indicator to distinguish water masses whose chemical and physical properties are unknown or too small to be analysed.

Literature

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A STUDY ON THE PRODUCTIVITY OF TANABE BAY
(Part II)

III. Oceanographic Conditions of Tanabe Bay (2)
Stratification and Fluctuation of Hydrological Conditions on Two Sectional Survey Lines

By
Shin-ichiro Fuse
(Seto Marine Biological Laboratory, Kyoto University)

Introduction

The concrete knowledge on the circulation of matters contained in sea water is a premise of the study on the bio-productive system of a bay.

In the previous report based on the first survey in November of 1956, the horizontal distribution only of the hydrological conditions was described, as the water was well mixed vertically, and it was concluded that the open sea water entered into the bay southeastwards in the form of a wedge to reach somewhere between the two islets Hatake-zima and Ka-sima (FUSE et al. 1958).

In this report are given the data on the vertical distribution of various hydrological conditions, basing on the result of the second survey in the summer of 1957.

Method, Location of Survey Lines and Meteorological Conditions

In the second survey, two sectional observations were made, one across the mouth of Tanabe Bay between two promontories of Bansyo-no-hana and Morisaki (B–M section), and the other along the line between Hatake-zima islet and Ka-sima islet in the inner part of the bay (H–K section) (Fig. 1).

On 11th August 1957, the vertical water sampling and temperature measurement in every 5 m layer were made at an hour interval during one tidal cycle (08:00~19:00), on board the surveying boats anchored at five stations on B–M line. On 30th August, the same survey was made on board a surveying boat, running along the H–K line at every one hour, during one tidal cycle (08:00~19:00). On this line, therefore, observations were made successively from a station to the next.

Water samples were treated chemically in the laboratory by the same methods as were previously reported (FUSE et al. 1958).

Meteorological conditions during these two surveys were as follows:

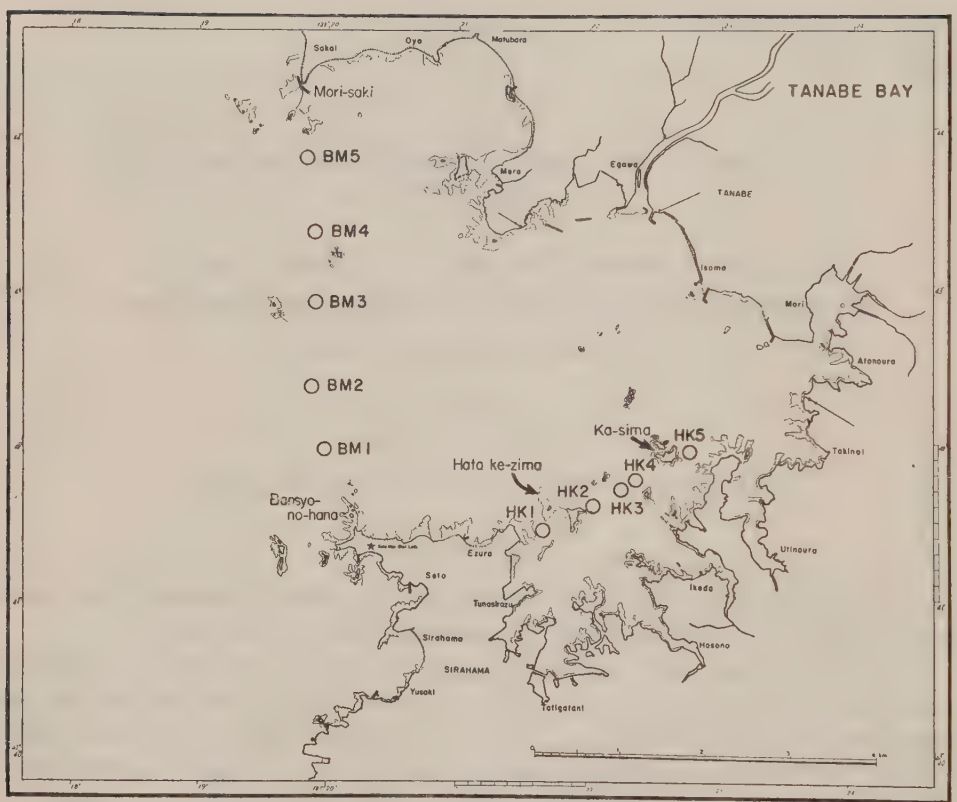

Fig. 1. Map of surveyed area.

A) B–M line, 11th August, 1957.

Time	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
Weather	cloudy	cloudy	cloudy	rainy	fine	fine	cloudy	cloudy	cloudy
Amount of clouds	10	9	9	9	5	6	9	9	8
Wind direction	S	SW	SW	W	SW	SW	SW	NE	N
Wind velocity[1]	1	1	2	1	1	1	2	2	2
Swell[2]	0	0	0	1	1	0	0	0	0
Wave	1	1	2	1	1	1	2	2	2
Air temperature (°C)	30.1	30.4	31.5	—	29.7	—	29.5	28.2	28.0

B) H–K line, 30th August, 1957. (observed at 9:00)
Weather: fine, Amount of clouds: 1, Wind direction: SSW, Wind velocity[1]: 0~1, Swell[2]: 0, Wave: 0~1, Air temperature: 27.4°C.

1) Beaufort's scale
2) Douglass's scale

silicates in both the bay mouth and the inner part are given in Tables I and II.

Full data on the distribution of temperature, chlorinity, phosphates and

1. Temperature

On B–M section, water temperature measured between 28.7°C (0 m, St. BM 3, 12:00) and 20.65°C (25 m layer, St. BM 1, 16:00). On H–K section, it measured between 29.24°C (0 m, St. HK 5, 16:00) to 25.40°C (bottom, St. HK 3, 15:27). In general, the temperature showed a tendency to become gradually lower from surface to bottom (Fig. 2–a). Namely, the average surface water temperature was 27.8°C on B–M section and 28.87°C on H–K section, in contrast to the bottom water temperature of 23.5°C on the former section and 26.56°C on the latter section.

2. Chlorinity

On B–M section, chlorinity measured between 19.04‰ (25 m layer, St. BM 2, 18:00) and 17.86‰ (0 m, St. BM 4, 09:00 and 10:00). On H–K section,

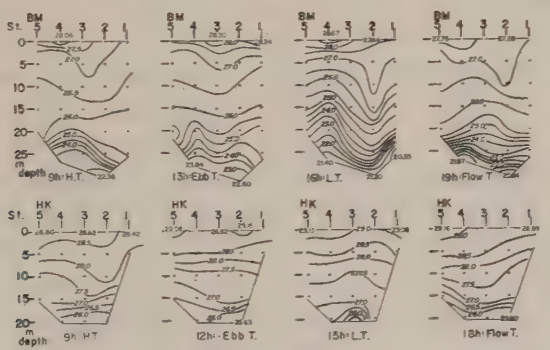

Fig. 2–a. Vertical distribution of water temperature (upper: B–M section, lower: H–K section).

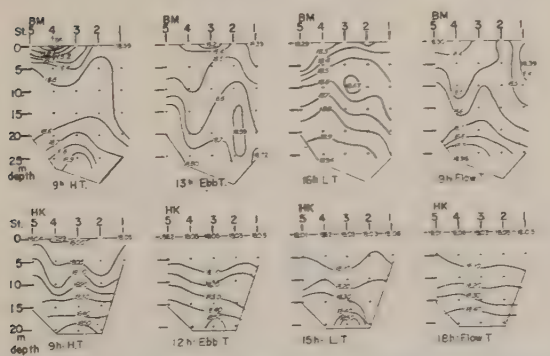

Fig. 2–b. Vertical distribution of chlorinity (upper: B–M section, lower: H–K section).

it measured between 18.57 ‰ (Bottom, St. HK 3, 15:27) and 17.96 ‰ (0 m, St. HK 5, 09:00 and 13:30). Chlorinity showed a tendency of becoming higher from surface to bottom (Fig. 2–b). Namely, while the average surface chlorinity was 18.25 ‰ on the former section and 18.03 ‰ on the latter section, the corresponding values in the bottom water were 18.74 ‰ and 18.37 ‰.

3. Phosphates and Silicates

The highest content of inorganic phosphates measured was 0.56 μg-atoms P/L on B–M section, and 0.41 μg-atoms P/L on H–K section. The lowest value was 0.00 μg-atoms P/L on both sections. The highest inorganic silicates content was 45.87 μg-atoms Si/L on the former section, and 14.53 μg-atoms Si/L on the latter section. The lowest was 3.45 μg-atoms Si/L on the former section and 2.27 μg-atoms Si/L on the latter section.

The values of both phosphates and silicates contents were exceptionally higher at St. BM 3 than at other stations. Excepting this station, there were little differences between H–K and B–M sections. Namely, average values were 0.13 μg-atoms P/L on H–K section, 0.12 μg-atoms P/L on B–M section 8.10 μg-atoms Si/L on H–K section and 7.32 μg-atoms Si/L on B–M section.

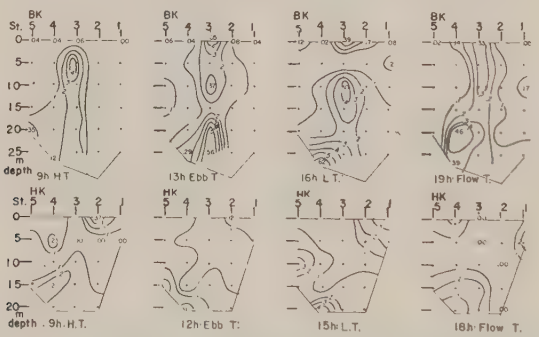

Fig. 3–a. Vertical distribution of phosphates (upper: B–M section, lower: H–K section).

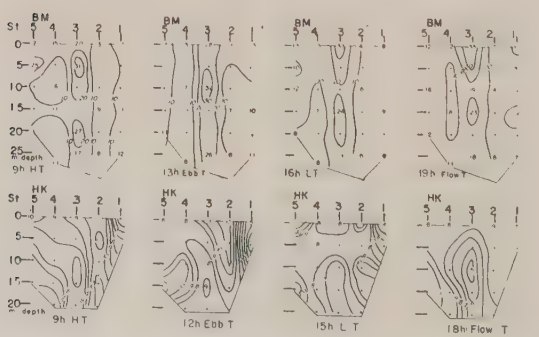

Fig. 3–b. Vertical distribution of silicates (upper: B–M section, lower: H–K section).

In contrast to the chlorinity and temperature, both phosphates and silicates did not show any marked stratification (Fig. 3).

Discussion

1. Stratification of water masses in summer

As compared with the results of the first survey in the autumn of 1956, the vertical range of water temperature and chlorinity of the second survey is larger on both sections B–M and H–K. Namely, in November 1956, the average range of temperature and chlorinity between the surface and the deepest layer was 0.44°C and 0.10‰ respectively near the mouth and 0.40°C and 0.09‰ respectively in the inner part of the bay. In August of 1957, the corresponding values were 4.3°C and 0.49‰ on the B–M section, and 2.31°C and 2.31‰ on the H–K section.

By a comparison of the vertical distribution of temperature and chlorinity in August 1957 and November 1956 (Figs. 2 and 4) as well as from the calculated values of σ_t it becomes evident that the water masses observed in 1957 were clearly more stable and better stratified than those in 1956. The vertical stability or the degree of vertical mixing of water masses depends on the heating in summer and the cooling in winter of the surface water.

The temperature of the surface layer near the mouth of the bay was 21～22°C in June (result of routine observation at the seashore by Seto Mar. Biol. Lab.), and the same temperature was measured in the bottom water in this summer survey. In May, the open sea water 10 miles west of Seto-zaki outside of the bay showed the same temperature from the surface to the bottom, and it was in June that 27°C on the surface and 21°C on 50 m layer were observed (Wakayama Prefectural Fishery Experimental Station, 1955, 1956). From these observations it may be concluded that the water mass in Tanabe Bay began to stratify and became stable after June.

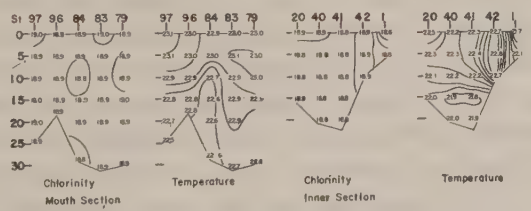

Fig. 4. Vertical distribution of temperature and chlorinity in November 1956.

In the case of phosphates and silicates, however, no marked tendency of stratification was observed. This fact may be due to the effects of some biological factors, which act independently of the movement of water masses.

2. Fluctuations of hydrological conditions

In the B–M section near the mouth of the bay, bottom chlorinity showed a regular hourly change with the minimum at 10:00 and the maximum at 16:00.

The same tendency was seen, in decreasing scales, in the upper layers, to be lost in the surface and the 5 m layers, especially at St. BM 1, where the chlorinity on the surface was nearly the same as that of 5 m layer. The irregularity of the stratification observed at St. BM 2 cannot be explained at present.

The water temperature changed synchronously with the chlorinity (it was minimal at 14:00, and maximal at 08:00). This tendency was the most remarkable on the deepest layer, and the amplitude of fluctuation became smaller upwards. The fluctuation in the water of shallower layers than 5 m was not larger than that in the bottom water, though the former was affected by the solar radiation (the maximum surface temperature occurred at 14:00).

Comparing the temperature and chlorinity in the surface and the 5 m layer at St. BM 1, the former fluctuated more than the latter: while the surface chlorinity of this station varied between 18.36‰ and 18.41‰, the range (0.05 ‰) of which corresponded to 11% of the maximum fluctuational range (0.46 ‰), the surface temperature varied between 26.77°C and 28.24°C, whose range (1.47°C) was about 22% of the maximum range (6.54°C). This may be due to that while the chlorinity of water masses passing through this station during the period of 12 hours is homogenized by mixing, the temperature is affected by the solar radiation. In the surface layer at St. BM 3~5, the greater fluctuation of chlorinity may be due to unmixed water masses influenced by both rainfall and fresh water influx into the bay.

In the inner section of the bay, the mode of fluctuation of temperature and chlorinity is slightly different from that in the outer section. Namely, the type of fluctuation is different between the shallower layers than 5 m and the deeper layers than 10 m, and the synchronous change is seen in temperature and chlorinity. It is especially noteworthy that the surface temperature shows the maximum at 14:00~16:00 at every station. The change of temperature in the surface and deep layers is independent of each other.

Concerning the temperature fluctuation of shallower layers, it may be said that the influence of solar radiation is more evident in the inner part of the bay. Near the mouth of the bay, the solar radiation is not so effective on the water temperature, owing to the violent turbulence. Factors influencing the temperature of deeper layers than 10 m may possibly be more complex, the reasons for which remain unknown. The chlorinity fluctuation in the inner part of the bay is not so remarkable as that near the mouth of the bay. This fact may be explained by that water masses on each layer are horizontally homogenized as the outer and inner waters of H–K line pass through different passages at ebb and flow tides. On the shallower layers than 5 m, however, the values of chlorinity are more variable, perhaps owing to the possible vertical mixture.

On the B–M line, the phase of hourly change in both chlorinity and deeper water temperature is about 2 hours in advance to the corresponding phase of the tide. This phenomenon may be explained by assuming that various water

masses passing through one station at the flow tide may be carried away from other stations at the ebb tide, and that the changes in the velocity and direction of current as well as the mixing process of water masses are not in conformity with the tidal rhythm. The correlation between the factors affecting the characters of water masses and tidal currents or tidal periodicity thus becomes very complicate.

3. Fluctuations of phosphates and silicates

Concerning the contents of phosphates and silicates, there is little difference between those of the outer and inner sections of the bay, excepting the value at St. BM 3, where unusually high contents of these matters and a wide fluctuation range were observed. It is also noteworthy that the fluctuation was more conspicuous in layers of higher contents of phosphates and silicates. This tendency was more remarkable at St. BM 3 than at any other stations on B–M line and at every station on H–K line. This peculiarity may have occurred by the interference of a rocky reef (Okino-sima), which is located along this line.

Summary

1. Sectional observations of hydrological conditions were made on two survey lines, B–M and H–K, the former traversing the mouth of Tanabe Bay from Bansyo-no-hana to Mori-saki, and the latter lying in the inner part of the bay between Hatake-zima and Ka-sima, during the period of one tidal cycle in August 1957.

2. Fluctuations and vertical distribution of water temperature, chlorinity, phosphates and silicates are described and discussed, in comparison with the results of the first survey which was carried out in November 1956 (FUSE et al. 1958).

3. Water masses were stratified vertically as considered from the conditions of chlorinity and temperature distribution.

4. In the mouth of the bay, both the water temperature and the chlorinity changed synchronously with one cycle during 12 hours period. In the inner part of the bay, they have a small range of fluctuation.

5. Water masses pass through different passages at ebb and flow tides. In the inner part of the bay, the homogenization of waters occurs on each hydrographic layer and the waters are mixed more profoundly in the inner bay than near the mouth.

6. The distribution of phosphates and silicates seems to be affected by some biological factors independent of the movement of water masses.

References

FUSE, S., YAMAZI, I. and HARADA, E. 1958. Rec. Oceanogr. Works in Japan, Special Number 2, pp. 3–8.

Wakayama Prefectural Fishery Experimental Station. 1955–1956. Oceanographical Table of Kii Strait.

Table I. Hydrological data for survey stations on a line between Bansyo-no-hana and Mori-saki near the mouth of Tanabe Bay, August 11th, 1957.

(A) Water Temperature (°C)

(Depth)	(Hour)											
(m)	8	9	10	11	12	13	14	15	16	17	18	19
St. BM1												
0	26.81	26.85	26.77	26.85	27.19	28.24	27.22	27.78	27.52	27.19	27.44	27.04
5	26.66	26.74	26.67	26.75	26.66	26.63	26.65	26.73	26.84	26.94	27.09	26.80
10	26.26	26.37	26.64	26.54	26.35	26.28	26.52	26.60	26.51	26.99	26.84	26.70
15	25.84	26.10	26.14	26.25	26.26	25.99	25.91	25.47	25.12	26.57	26.08	26.43
20	25.63	25.77	26.06	26.16	25.33	24.77	24.07	24.58	24.76	24.61	25.68	25.63
25	25.76	25.72	26.11	25.02	24.66	24.79	22.10	21.82	20.65	22.32	23.81	23.18
St. BM2												
0	27.13	27.20	27.36	28.08	28.16	28.00	28.34	27.48	27.44	28.24	27.56	27.28
5	26.92	26.97	27.18	27.02	26.91	26.86	27.00	27.01	26.90	27.29	26.91	27.15
10	26.69	26.84	26.88	26.62	26.70	26.47	26.50	26.66	26.92	27.06	26.70	27.03
15	26.28	26.23	26.39	26.33	26.37	26.21	26.09	26.92	27.00	26.01	—	26.01
20	25.30	25.69	25.88	26.26	26.09	25.21	23.89	—	25.13	24.84	25.98	25.67
25	24.56	25.05	25.20	25.59	24.05	24.05	22.55	22.22	—	23.92	22.12	23.64
B	22.47	22.36	22.92	23.54	23.33	22.60	21.75	21.13	21.20	21.06	21.14	20.84
St. BM3												
0	—	27.8	28.5	28.5	28.7	28.3	28.4	28.0	28.05	27.8	28.1	27.3
5	—	27.2	27.3	27.0	27.2	27.2	27.3	27.3	26.9	27.0	26.4	27.0
10	—	26.9	26.5	26.7	26.7	26.8	26.8	26.5	26.3	26.4	26.3	26.4
15	—	26.3	26.4	26.5	26.3	26.2	26.1	26.1	25.8	26.0	26.1	25.9
20	—	25.7	25.8	25.6	25.8	25.7	25.2	25.4	24.6	24.6	24.7	24.6
25	—	23.7	24.0	24.3	24.4	24.8	24.6	24.4	23.3	23.7	23.8	23.8
St. BM4												
0	28.08	28.06	27.96	28.06	27.76	27.55	27.71	28.20	28.67	28.06	27.84	27.86
5	26.62	26.62	26.74	26.87	26.84	26.63	26.65	26.42	26.63	26.74	26.74	27.14
10	26.33	26.67	26.74	26.79	26.67	26.57	25.98	25.83	25.76	25.90	26.53	26.44
15	26.03	26.12	26.13	26.26	26.14	26.02	25.31	24.62	23.94	24.03	25.82	26.11
20	25.54	25.52	25.74	25.91	25.76	24.88	24.51	23.53	22.80	22.15	22.94	25.47
25	23.23	23.54	23.54	23.49	23.74	23.84	23.33	22.46	21.40	21.25	21.48	21.85
St. BM5												
0	27.65	27.86	27.74	27.65	27.57	27.50	27.67	27.86	28.27	28.36	27.96	27.76
5	26.74	26.63	26.74	26.94	26.94	26.74	26.84	26.94	26.96	26.89	26.96	26.74
10	26.43	26.35	26.45	26.92	26.74	26.43	26.14	25.84	26.00	26.12	26.52	26.63
15	26.23	26.23	26.33	26.25	26.25	25.92	25.61	25.53	25.12	24.51	25.83	26.23
20	26.21	26.23	26.00	26.21	26.02	25.61	25.36	23.43	23.51	23.41	25.61	25.97

Table I. Hydrological data for survey stations on a line between Bansyo-no-hana and Mori-saki near the mouth of Tanabe Bay, August 11th, 1957 (continued).

(B) Chlorinity (‰)

(Depth) (m)	(Hour) 8	9	10	11	12	13	14	15	16	17	18	19
St. BM1												
0	18.39	18.39	18.39	18.41	18.39	18.39	18.39	18.39	18.39	18.39	18.36	18.41
5	18.41	18.41	18.41	18.41	18.42	18.39	18.41	18.41	18.41	18.41	18.39	18.39
10	18.41	18.41	18.44	18.47	18.45	18.51	18.54	18.48	18.51	18.45	18.45	18.45
15	18.56	18.48	18.54	18.50	18.53	18.56	18.59	18.54	18.54	18.51	18.50	18.51
20	18.66	18.50	18.54	18.53	18.54	18.60	18.69	18.68	18.66	18.57	18.56	18.60
25	18.69	18.69	18.59	18.54	18.66	18.72	18.84	18.96	18.80	18.80	18.78	18.74
St. BM2												
0	18.47	18.45	18.43	18.27	18.36	18.46	18.36	18.27	18.27	18.47	18.39	18.53
5	18.50	18.56	18.54	18.39	18.56	18.57	18.48	18.43	18.53	18.42	18.45	18.51
10	18.60	18.53	18.51	18.43	18.54	18.68	18.57	18.56	18.56	18.54	18.53	18.53
15	18.59	18.57	18.53	18.53	18.56	18.50	18.57	18.60	18.66	18.54	—	18.59
20	18.57	18.68	18.65	18.68	18.68	18.59	18.77	18.80	18.81	18.83	18.65	18.63
25	18.77	18.72	18.61	18.68	18.83	18.59	18.97	18.97	18.90	18.87	19.04	18.86
St. BM3												
0	—	18.21	18.12	18.16	18.22	18.21	18.24	18.39	18.39	18.36	18.43	18.43
5	—	18.37	18.42	18.42	18.54	18.54	18.54	18.57	18.54	18.59	18.56	18.45
10	—	18.56	18.57	18.57	18.56	18.56	18.54	18.57	18.47	18.65	18.65	18.60
15	—	18.54	18.54	18.60	18.61	18.60	18.62	18.63	18.65	18.63	18.63	18.63
20	—	18.74	18.66	18.70	18.72	18.65	18.75	18.74	18.81	18.77	18.80	18.75
25	—	18.92	18.89	18.89	18.81	18.78	18.82	18.91	18.92	18.88	18.88	18.92
St. BM4												
0	17.89	17.86	17.86	18.03	18.21	18.35	18.33	18.32	18.23	18.23	18.18	18.32
5	18.44	18.42	18.48	18.48	18.45	18.48	18.48	18.51	18.48	18.44	18.42	18.45
10	18.48	18.53	18.50	18.44	18.48	18.48	18.59	18.63	18.63	18.63	18.50	18.48
15	18.56	18.54	18.59	18.47	18.56	18.57	18.63	18.74	18.81	18.78	18.63	18.51
20	18.62	18.62	18.59	18.57	18.60	18.59	18.63	18.80	18.89	18.92	18.92	18.71
25	18.84	18.83	18.94	18.84	18.78	18.80	18.92	18.92	18.94	19.01	19.00	18.96
St. BM5												
0	17.99	18.09	18.05	18.24	18.35	18.45	18.30	18.29	18.29	18.27	18.26	18.30
5	18.50	18.50	18.48	18.50	18.45	18.42	18.48	18.47	18.24	18.48	18.45	18.47
10	18.57	18.48	18.59	18.45	18.50	18.56	18.56	18.57	18.63	18.62	18.51	18.62
15	18.57	18.53	18.56	18.50	18.57	18.77	18.63	18.59	18.71	18.78	18.72	18.59
20	18.62	18.56	18.63	18.57	18.59	18.68	18.63	18.83	18.88	18.86	18.63	18.62

Table I. Hydrological data for survey stations on a line between Bansyo-no-hana and Mori-saki near the mouth of Tanabe Bay, August 11th, 1957 (continued).

(C) Phosphate-P (μg-Atoms/L)

(Depth) (m)	(Hour) 8	9	10	11	12	13	14	15	16	17	18	19
St. BM1												
0	.00	.00	.00	.04	.00	.04	.04	.04	.08	.12	.17	.08
5	.08	.08	.12	.00	.08	.08	.08	.04	.12	.08	.04	.08
10	.04	.04	.08	.12	.08	.08	.04	.17	.08	.04	.04	.17
15	.08	.04	.12	.04	.02	.04	.04	.08	.12	.00	.04	.00
20	.06	.06	.12	.06	.02	.04	.12	.12	.08	.08	.04	.08
25	.08	.04	.04	.12	.10	.10	.21	.21	.21	.10	.10	.12
St. BM2												
0	.12	—	.54	.08	.04	.08	.08	.12	.17	.04	.04	—
5	.08	.04	.08	.08	.04	.12	.12	.04	.06	.12	.00	.12
10	.12	.06	.14	.17	.04	.19	.14	.12	.12	.17	.04	.04
15	.12	.04	.02	.06	.06	.08	.12	.04	.08	.04	—	.12
20	.04	.02	.08	.08	.00	.04	.12	.08	.08	.04	.00	.02
25	.12	.08	.12	.14	.12	.04	.17	.10	.06	.12	.04	.12
St. BM3												
0	—	.06	.21	.31	.19	.50	.21	.19	.39	.25	.08	.33
5	—	.41	.19	.21	.25	.23	.75	.37	.04	.37	.50	.33
10	—	.27	.27	.17	.31	.37	.25	.21	.50	.29	.21	.35
15	—	.25	.19	.41	.17	.19	.39	.37	.39	.33	.21	.21
20	—	.25	.21	.25	.50	.54	.37	.37	.21	.25	.29	.39
25	—	.27	.41	.39	.39	.56	.25	.21	.31	.19	.19	.23
St. BM4												
0	.08	.04	.02	.08	.04	.04	.00	.00	.02	.06	.10	.14
5	.04	.04	.08	.00	.00	.14	.04	.02	.04	.02	.04	.04
10	.04	.00	.02	.04	.04	.04	.10	.08	.17	.06	.14	.08
15	.12	.12	.12	.00	.02	.06	.06	.04	.14	.06	.10	.14
20	.12	.08	.12	.29	.08	.17	.08	.21	.17	.14	.33	.46
25	.17	.12	.21	.37	.29	.29	.21	.44	.62	.17	.25	.39
St. BM5												
0	.02	.04	.06	.10	.14	.06	.08	.19	.12	.00	.04	.02
5	.02	.02	.00	.12	.12	.02	.10	.10	.04	.08	.04	.06
10	.04	.04	.08	.08	.06	.12	.12	.04	.04	.14	.06	.06
15	.04	.08	.02	.08	.08	.12	.08	.04	.04	.29	.62	.04
20	.25	.35	.12	.12	.04	.00	.06	.05	.12	.10	.10	.04

Table I. Hydrological data for survey stations on a line between Bansyo-no- hana and Mori-saki near the mouth of Tanabe Bay, August 11th, 1957 (continued).

(D) Silicate-Si (μg-Atoms/L)

(Depth) (m)	(Hour) 8	9	10	11	12	13	14	15	16	17	18	19
St. BM1												
0	12.23	10.70	11.08	9.93	16.05	12.62	16.82	10.72	7.65	9.17	—	10.72
5	16.05	8.42	11.47	9.17	8.42	11.47	6.88	8.42	7.65	12.23	10.32	8.80
10	10.70	11.47	9.17	11.68	11.68	9.55	7.65	9.17	6.88	9.17	8.42	7.65
15	13.00	10.32	15.67	10.70	10.32	9.93	9.17	8.42	9.17	11.08	8.42	19.50
20	13.77	13.77	7.27	11.08	11.47	9.93	9.55	14.92	9.55	9.55	6.88	9.93
25	11.08	11.47	11.08	—	11.47	10.70	8.42	7.65	9.17	12.23	12.23	6.88
St. BM2												
0	9.77	8.42	9.17	11.08	8.80	11.08	11.08	14.92	9.55	8.42	7.27	6.88
5	6.88	7.27	9.93	8.03	8.03	9.93	6.50	8.42	8.03	11.08	10.72	7.27
10	7.65	6.88	6.12	5.35	6.12	4.58	8.42	4.58	4.97	4.58	6.12	4.20
15	6.12	8.42	3.82	4.58	4.58	7.27	7.27	7.65	7.27	4.58	—	5.35
20	3.87	3.45	4.20	4.58	7.27	4.20	6.12	7.27	3.82	6.88	3.82	4.20
25	4.58	7.65	6.88	6.88	5.35	8.42	4.97	11.47	4.97	3.45	3.45	7.65
St. BM3												
0	—	19.88	22.17	22.17	20.65	28.28	31.35	26.77	37.47	22.17	27.52	34.40
5	—	30.58	26.77	24.47	26.77	29.82	21.40	22.17	26.77	21.40	40.51	30.58
10	—	23.70	17.58	27.51	26.77	30.58	22.17	26.00	19.88	16.82	24.47	19.12
15	—	15.28	26.00	23.70	17.58	26.77	12.23	9.93	23.70	18.35	21.40	22.71
20	—	26.77	16.05	22.17	23.70	28.28	36.70	23.70	23.70	26.00	36.70	16.05
25	—	19.12	35.16	29.82	32.87	26.00	45.87	26.77	19.12	18.73	19.50	18.35
St. BM4												
0	14.15	15.28	11.47	9.55	12.62	7.65	7.65	11.47	13.00	14.53	21.78	11.47
5	6.88	9.77	7.65	9.77	11.48	6.50	6.12	8.02	11.47	6.88	6.88	7.26
10	7.65	6.50	7.25	10.72	8.42	6.88	6.88	7.26	7.26	11.47	8.42	8.80
15	9.55	10.72	7.65	9.17	10.72	7.65	11.85	9.93	7.27	7.27	7.27	8.42
20	7.65	7.65	9.93	7.65	7.65	6.12	11.47	8.42	8.42	7.65	9.77	9.77
25	11.47	10.70	7.65	7.65	11.47	7.65	11.08	7.65	7.65	10.70	10.70	10.70
St. BM5												
0	18.73	12.23	11.47	8.42	11.47	14.53	13.77	15.28	13.00	15.28	13.00	11.47
5	8.03	25.23	18.35	19.12	19.50	19.12	19.88	7.65	9.77	9.77	10.70	14.53
10	9.17	8.42	8.79	13.38	11.47	12.23	11.47	11.08	11.85	11.85	10.70	15.67
15	6.88	10.72	6.88	23.70	10.72	11.47	10.32	8.42	12.23	11.47	10.72	17.58
20	8.03	8.78	8.03	7.26	7.26	10.72	9.17	14.53	7.65	11.47	8.42	12.23

Table II. Hydrological data for survey stations on a line between Hatake-zima and Ka-sima in the inner part of Tanabe Bay, August 30th, 1957.

(A) Water Temperature (°C)

(Depth) (m)	(Hour)									
St. HK1	08:00	09:55	10:10	11:57	12:25	14:14	15:08	16:50	17:17	18:52
0	28.35	28.42	28.62	28.82	28.88	29.20	29.08	29.06	29.08	28.89
B	28.03	27.98	28.04	28.45	28.27	28.52	28.94	28.67	28.37	28.00
St. HK2	08:14	09:42	10:22	11:50	12:35	14:00	15:18	16:38	17:27	18:41
0	28.37	28.72	28.70	28.92	29.16	29.18	28.90	29.04	29.08	28.67
5	28.35	28.39	28.35	28.27	28.24	28.51	28.20	28.43	28.43	28.45
10	27.83	28.52	27.27	27.21	27.34	27.37	27.71	27.53	27.43	27.35
15	27.33	27.02	26.97	26.93	27.04	27.09	27.27	27.13	27.18	27.25
B	25.92	25.72	26.36	25.82	25.63	25.59	27.14	25.46	25.51	25.80
St. HK3	08:30	09:34	10:30	11:34	12:45	13:51	15:27	16:27	17:35	18:33
0	28.45	28.62	28.80	28.78	28.92	29.01	28.98	29.05	29.02	28.93
5	28.37	28.41	28.37	28.49	28.52	28.51	28.49	28.57	28.98	28.69
10	27.92	27.75	27.47	27.16	27.27	27.50	27.23	27.50	27.69	27.65
15	27.27	27.51	27.17	27.02	27.08	27.00	27.20	27.13	27.25	27.47
B	26.29	25.60	26.84	25.51	25.44	25.67	25.40	25.92	25.61	25.71
St. HK4	08:42	09:27	10:36	11:22	12:50	13:44	15:32	16:23	17:40	18:28
0	28.40	28.62	28.78	28.88	28.96	29.03	29.13	29.03	29.03	29.08
5	28.35	28.35	28.35	28.42	28.55	28.59	28.80	28.55	29.00	28.98
10	28.23	27.49	27.42	27.61	27.44	27.42	27.71	27.78	27.63	27.71
15	27.07	27.36	26.92	26.96	26.95	27.13	27.10	27.50	27.57	27.25
B	25.61	25.72	25.81	25.73	26.42	25.92	26.74	25.54	25.81	25.97
St. HK5	09:00	09:10	10:50	11:10	13:05	13:30	15:47	16:08	17:55	18:14
0	28.76	28.80	28.88	28.68	29.08	29.16	29.15	29.24	29.09	29.16
5	28.27	28.41	28.45	28.49	28.55	28.58	28.47	28.49	28.82	28.66
10	28.55	27.44	27.17	27.18	27.27	27.43	27.70	27.60	27.82	27.83
B	27.25	—	26.74	26.65	26.50	26.63	27.11	27.73	26.96	26.04

Table II. Hydrological data for survey stations on a line between Hatake-zima and Ka-sima in the inner part of Tanabe Bay, August 30th, 1957 (continued).

(B) Chlorinity (‰)

(Depth) (m)	(Hour)									
St. HK1	08:00	09:55	10:10	11:57	12:25	14:14	15:08	16:50	17:17	18:52
0	18.05	18.05	18.05	18.05	18.05	18.05	18.06	18.05	18.05	18.05
B	18.02	18.05	18.05	18.05	18.05	18.02	18.02	18.02	18.05	18.05
St. HK2	08:14	09:42	10:22	11:50	12:35	14:00	15:18	16:38	17:27	18:41
0	18.02	18.02	18.05	18.02	18.03	18.03	18.03	18.05	18.05	18.05
5	18.03	18.03	18.03	18.05	18.06	18.06	18.12	18.06	18.05	18.05
10	18.21	18.06	18.20	18.18	18.27	18.14	18.20	18.14	18.17	18.15
15	18.35	18.32	18.26	18.27	18.29	18.26	18.27	18.35	18.32	18.24
B	18.45	18.47	18.39	18.47	18.47	18.47	18.26	18.48	18.51	18.50
St. HK3	08:30	09:34	10:30	11:34	12:45	13:51	15:27	16:27	17:35	18:33
0	17.99	17.99	18.00	18.05	18.05	18.05	18.03	18.03	18.05	18.03
5	18.02	18.05	18.06	18.05	18.03	18.02	18.08	18.02	18.05	18.05
10	18.17	18.20	18.20	18.20	18.20	18.15	18.12	18.12	18.06	18.17
15	18.35	18.35	18.27	18.20	18.32	18.30	18.30	18.27	18.32	18.23
B	18.50	18.53	18.53	18.53	18.53	18.50	18.57	18.50	18.50	18.50
St. HK4	08:42	09:27	10:36	11:22	12:50	13:44	15:32	16:23	17:40	18:28
0	18.02	17.99	18.02	18.00	18.05	18.03	18.02	18.05	18.05	18.06
5	18.00	18.03	18.05	18.03	18.05	18.05	18.02	18.03	18.05	18.00
10	18.09	18.08	18.17	18.20	18.20	18.20	18.20	18.11	18.11	18.24
15	18.29	18.38	18.38	18.35	18.38	18.28	18.32	18.31	18.31	18.35
B	18.53	18.50	18.52	18.50	18.43	18.49	18.38	18.52	18.50	18.47
St. HK5	09:00	09:10	10:50	11:10	13:05	13:30	15:47	16:08	17:55	18:14
0	17.96	18.04	18.04	17.99	18.02	17.96	18.01	18.11	18.02	18.01
5	18.13	18.11	18.07	18.07	18.08	18.07	18.10	18.08	18.05	18.11
10	18.25	18.26	18.22	18.37	18.29	18.26	18.17	18.25	18.14	18.11
B	18.26	—	18.32	18.41	18.43	18.41	18.38	18.26	18.34	18.34

Table II. Hydrological data for survey stations on a line between Hatake-zima and Ka-sima in the inner part of Tanabe Bay, August 30th, 1957 (continued).

(C) Phosphate-P (μg-Atoms/L)

(Depth) (m)	(Hour)									
St. HK1	08:00	09:55	10:10	11:57	12:25	14:14	15:08	16:50	17:17	18:52
0	.29	.15	.00	.06	.08	.00	.00	.02	.10	.10
B	.23	.00	.10	.29	.10	.12	.23	.02	.06	.25
St. HK2	08:14	09:42	10:22	11:50	12:35	14:00	15:18	16:38	17:27	18:41
0	.17	.37	.08	.00	.12	.12	.21	.19	.00	.04
5	.10	.00	.02	.15	.02	.08	.12	.00	.08	.08
10	.00	.02	.08	.08	.08	.15	.04	.02	.04	.00
15	.04	.04	.04	.10	.08	.04	.15	.08	.12	.08
B	.04	.17	.12	.12	.15	.08	.08	.10	.17	.00
St. HK3	08:30	09:34	10:30	11:34	12:45	13:51	15:27	16:27	17:35	18:33
0	.12	.04	.12	.00	.00	.00	.08	.02	.04	.00
5	.00	.00	.00	.00	.02	.02	.06	.02	.02	.00
10	.04	.19	.08	.02	.08	.06	.04	.19	.06	.06
15	.23	.15	.02	.06	.17	.17	.17	.15	.02	.27
B	.35	.10	.29	.12	.19	.17	.19	.06	.17	.21
St. HK4	08:42	09:27	10:36	11:22	12:50	13:44	15:32	16:23	17:40	18:28
0	.02	.19	.17	.00	.17	.17	.06	.23	.19	.21
5	.00	.23	.17	.12	.04	.27	.08	.17	.04	.08
10	.08	.04	.00	.06	.19	.19	.17	.15	.19	.06
15	.19	.21	.21	.15	.04	.23	.02	.19	.21	.29
B	.06	.17	.23	.27	.31	.00	.41	.37	.15	.35
St. HK5	09:00	09:10	10:50	11:10	13:05	13:30	15:47	16:08	17:55	18:14
0	.23	.19	—	.17	.10	.19	.04	.02	.08	.19
5	.19	.06	.08	.02	.17	.15	.15	.10	.02	.02
10	.33	.04	.15	.15	.15	.04	.31	.00	.02	.06
B	.19	—	.23	.41	.31	.27	.17	.02	.17	.19

Table II. Hydrological data for survey stations on a line between Hatake-zima and Ka-sima in the inner part of Tanabe Bay, August 30th, 1957 (continued).

(D) Silicate-Si (μg-Atoms/L)

(Depth) (m)	(Hour)									
St. HK1	08:00	09:55	10:10	11:57	12:25	14:14	15:08	16:50	17:17	18:52
0	9.17	4.58	4.97	4.58	4.58	4.58	4.20	4.20	8.03	6.50
B	9.17	7.27	6.50	7.27	2.27	6.50	6.50	11.08	6.87	6.50
St. HK2	08:14	09:42	10:22	11:50	12:35	14:00	15:18	16:38	17:27	18:41
0	11.08	10.70	9.17	9.17	11.47	11.47	10.32	10.72	9.38	9.17
5	10.72	11.08	12.22	11.47	11.47	10.72	8.37	8.37	9.17	8.37
10	11.08	10.32	8.37	9.17	11.08	8.03	10.32	7.65	8.03	8.80
15	10.72	11.47	8.37	10.72	9.17	9.17	9.88	8.80	7.65	8.37
B	10.72	11.08	8.80	9.17	8.03	8.42	7.65	7.65	10.72	7.65
St. HK3	08:30	09:34	10:30	11:34	12:45	13:51	15:27	16:27	17:35	18:33
0	10.70	9.17	10.70	8.42	10.72	7.65	7.65	7.65	7.27	8.03
5	8.42	8.42	9.77	10.72	8.42	9.17	8.42	8.42	7.27	6.12
10	6.17	6.17	7.27	8.03	6.88	6.88	6.50	8.03	8.42	4.58
15	7.27	6.88	6.50	7.27	7.27	7.27	6.88	8.03	4.58	5.35
B	7.65	7.65	10.72	8.03	6.88	6.17	6.50	6.88	6.88	6.50
St. HK4	08:42	09:27	10:36	11:22	12:50	13:44	15:32	16:23	17:40	18:28
0	10.32	8.80	8.42	11.47	8.42	8.42	7.65	8.42	7.65	8.03
5	7.65	8.42	9.17	9.17	8.03	9.17	8.42	8.42	9.17	8.03
10	7.27	7.65	7.65	8.42	10.72	8.03	8.03	7.27	7.65	7.65
15	8.42	9.77	11.47	8.42	10.32	7.65	7.27	8.42	8.03	9.55
B	9.77	10.72	10.72	11.85	6.88	8.80	8.80	13.77	11.47	9.17
St. HK5	09:00	09:10	10:50	11:10	13:05	13:30	15:47	16:08	17:55	18:14
0	13.77	9.77	9.17	11.47	8.42	8.80	11.08	7.65	8.42	8.42
5	9.77	7.65	8.42	8.80	8.42	8.80	8.42	8.03	8.03	8.42
10	11.08	9.77	10.72	11.08	8.42	9.17	8.42	11.47	8.42	10.32
B	11.85	—	10.72	14.53	11.47	13.00	10.72	8.80	11.85	10.32

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A STUDY ON THE PRODUCTIVITY OF TANABE BAY
(Part II)

IV. On the Voluminal Change of Plankton Communities Caused by Tidal Current

By

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The stagnant degree determines the physical, chemical and biological environment of inlet waters. The maintenance and distribution of the pelagic communities seem to depend on the dynamic balance between the dispersion and the reaction of the population to the change in environmental conditions caused by the water-mass mixing and movements. For the purpose to study on the voluminal change of plankton communities caused by the tidal current, two survey lines A and B across the bay were taken, one near the entrance of the bay and the other in the inner part, following the procedure of 1956 (HAYAMI et al, 1958). The physical survey was made simultaneously by the members of the Geophysical Institute of Kyoto University. In this report the result obtained on B line only is given. As is shown in Fig. 1, the survey line B is located in the inner part of the bay, traversing two islets Hatake-zima and Ka-sima between the Cape Sakata and the northern end of Torinosu Peninsula in a direction of SW–NE. Ten stations along this line were taken at nearly equal intervals.

Throughout this survey plankton samples were taken during one complete period of semi-diurnal tide on August 23, 26 and 29, 1957. Tidal records were taken at the same time by the self-recording tidal gauge at Mori, near the north-eastern corner of Tanabe Bay. The plankton were hauled vertically from 15 meters to the surface or from the depth near the bottom to the surface at Sts. 2 (from 6 m to the surface) and 10 (from 13 m to the surface). A modified Kitahara's quantitative tow net, with diameter of 11.2 cm and 25 cm respectively at the mouth and at the belly and 70 cm in length, was used for sampling. It was stretched with the No. XX–13 Müller's gauze and cut by its mouth 10 liters of water by one meter haul. The settling volume was measured with measuring cylinder after 24 hours.

The bottom configuration in this area is extremely complicated by the presence of many islets and rocky reefs, and produces an effective barrier against the exchange of water-masses. This barrier divides the bay into the outer and inner areas topographically and ecologically (YAMAZI, 1958). The

Fig. 1. Map of Tanabe Bay showing the stations.

depth of the inner area is largely about 20 meters, but along the line B it is relatively shallow. The passage where St. 2 is located is very shallow, measuring only about 7 meters in depth at high tide. The outer area of this line forms a shallow rocky basin. The current is relatively speedy at both flood and ebb tides. The depths at Sts. 4, 5 and 7 are about 19 meters at high tide. As the passages at Sts. 4 and 7 are deeper, the current seems to be rather strong, and the water volume passing through these passages is large. St. 10 is 13 meters deep and forms a narrow, rocky basin.

The meteorological data during the period of this survey are given in Table I. The maximal value of the tidal range of the sea level is about 1.5 m.

1. Observation on August 23, 1957.

The results of measurement on the settling volume and populations are graphically shown in Fig. 2. The low and high tide is 10:20 and 16:40 respectively. The plankton community at each station was of the strong embaymental type, but its components and population density were more or less different. In every observation both settling volume and population were the smallest at St. 2 near the southern coast and the largest at St. 7 near Ka-sima.

The volume of plankton fluctuated according to tidal changes. In general, the largest fluctuation occurred at low tide and became gradually smaller toward the high tide, although the rough settling volume did not vary distinctly. These facts seem to indicate that at low tide water-masses containing dense inlet

Table I.

Date	Moon age	Degree of swelling	Rainfall (mm)	Atmospheric pressure (mb)	Remarks
Aug. 19	(	4	0	1010	
20		4	0.95	1010	
21		2	5.15	1010	
22		2	10.70	1011	
23		0	24.10	1011	
24		2–3	22.30	1009	Typhoon No. 9
25	●	0	0	1018	
26		0	0.5	1018	
27		1	1.55	1018	
28		1	1.22	1015	
29		0	1.44	1013	

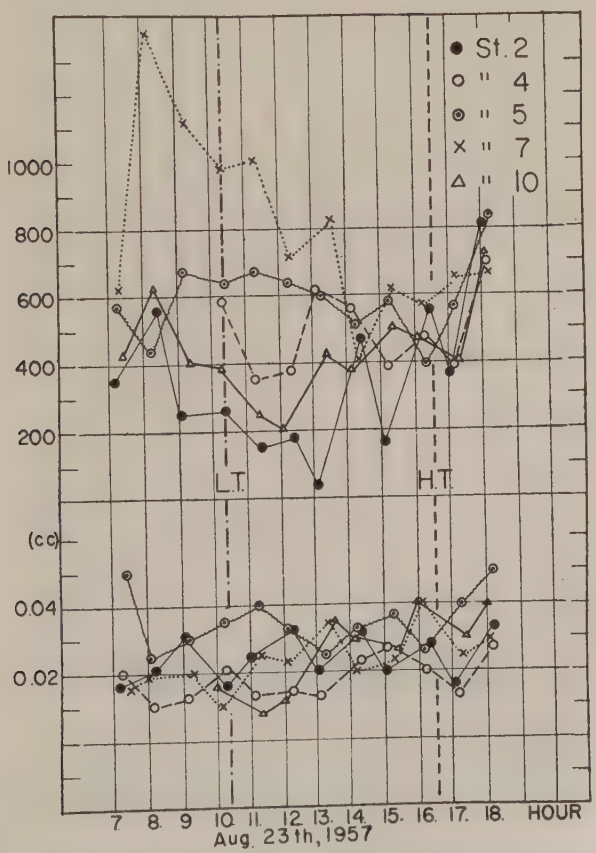

Fig. 2. Hourly change of plankton population (above) and settling volume (below) at each station, on August 23, 1957. H.T.....high tide, L.T. . . . low tide.

plankton population inside the area pass through these stations. At high tide, however, outer water-masses containing poor populations inflow through these stations.

2. Observation on August 26, 1957.

The low and high tide was at 12:20 and 16:40 respectively. The density of plankton communities and settling volume at each station are given in Fig. 3. These values were the greatest at St. 5 (from 500 to 1,100 individuals per 5 m hauls) and followed by those at St. 7. The largest fluctuation in number was found at St. 2, where it varied from 200 to 900 individuals per 5 m hauls. The fluctuation of density was larger than that on August 23. The Typhoon No. 9 passed through Sikoku on 24th and at that time the sea was relatively rough, but no appreciable effect was seen upon the inlet plankton communities. The settling volume and number of plankton along this survey line were generally similar to those on August 23.

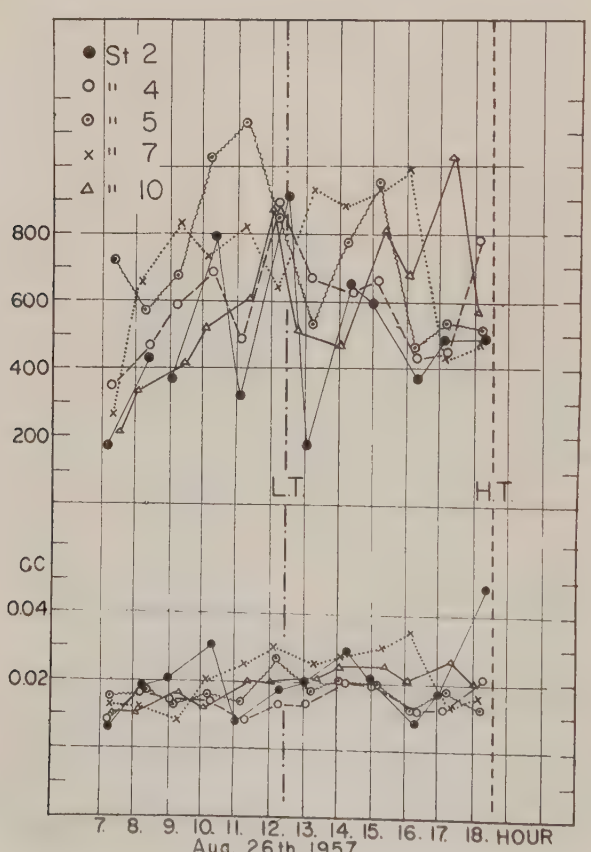

Fig. 3. Hourly change of plankton population (above) and settling volume (below) at each station, on August 26, 1957. H.T. . . . high tide, L.T. . . . low tide.

3. Observation on August 29, 1957.

The high and low tide was at 8:00 and 14:10 respectively. The quantity and population of plankton differed greatly from those of the foregoing two observations, the volume and number of plankton at each station being very small (Fig. 4). Probably due to the influence of Typhoon No. 9 (on August 24th), except the increase of the tidal range, the water-masses of the inner and outer parts of the bay became to mix together. The oceanic and neritic forms originating from the open sea were relatively abundant in species and populations at St. 5. The largest population at Sts. 5 and 4 was found at low tide. At other stations these values were not so variable from hour to hour.

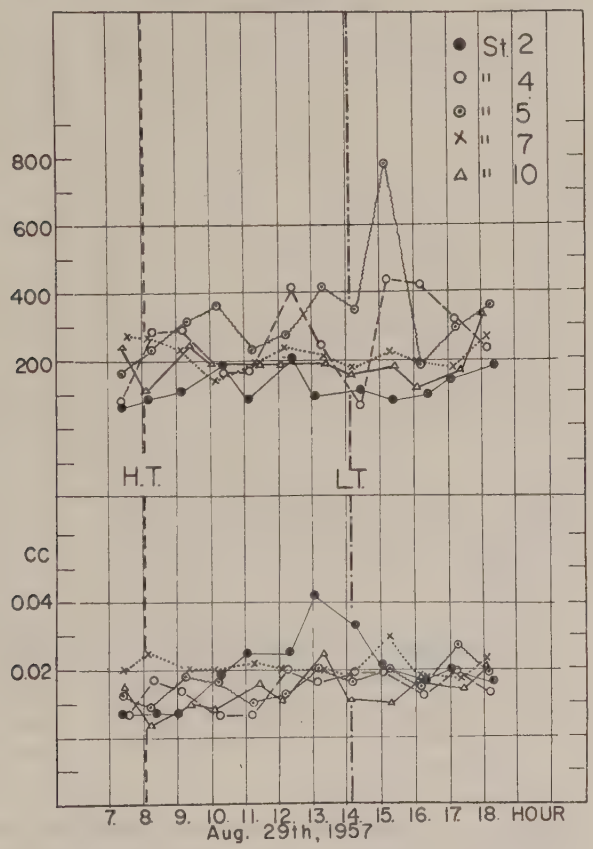

Fig. 4. Hourly change of plankton population (above) and settling volume (below) at each station, on August 29, 1957. H.T. . . . high tide, L.T. . . . low tide.

4. Hourly variations of plankton passing through Line B during the period from August 23 to 29.

Figure 5 shows the hourly change of the mean values of population at five stations. On August 23, a large value was observed at ebb tide along Line B

and decreased gradually and attained the minimum at high tide. On August 26 almost the same tendency was seen as on August 23. On August 29, however, the population was generally very small and its gradient was not conspicuous. In general, throughout these observations the population density was larger at ebb tide than at flood tide.

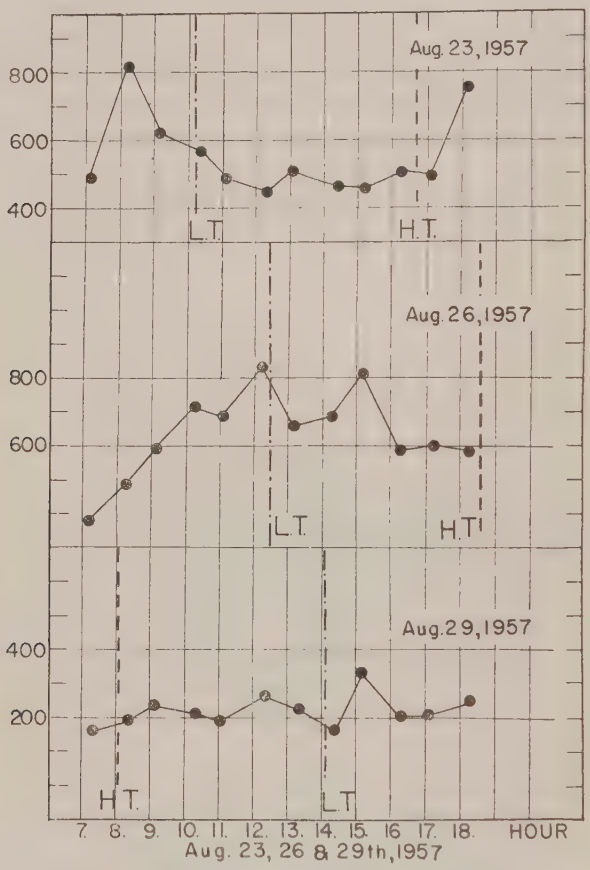

Fig. 5. Comparison of hourly change of mean plankton population at five stations between August 23–29.

5. Numerical variation of important plankton organisms caused by tidal current.

The variation of important plankton organisms observed at each station along Line B is shown in Figs. 6–10. In each of these graphs (Figs. 6–10), important species of inlet-water forms common in the inner part of the bay are given on upper lines, and those of oceanic forms temporarily intruded in the bay on lower lines. The fluctuation of occurrence in these species was conspicuous and very complex on account of the tidal change. As a whole, the population of the strong embaymental forms tended to increase at ebb tide and to decrease

at flood tide. On the other hand, more open-sea forms such as *Oithona rigida, Oncaea media, Oncaea venusta, Corycaeus* spp., *Paracalanus parvus* major form, *Oithona plumifera,* harpacticoid copepods, oceanic tunicates and chaetognaths etc. increased at flood tide more than at ebb tide. It is also noteworthy that *Microsetella rosea* and *Euterpe acutifrons,* and harpacticoids, which are usually very sparse in inlet waters, were fairly common inwards. This may be an effect of wind and swells by typhoon.

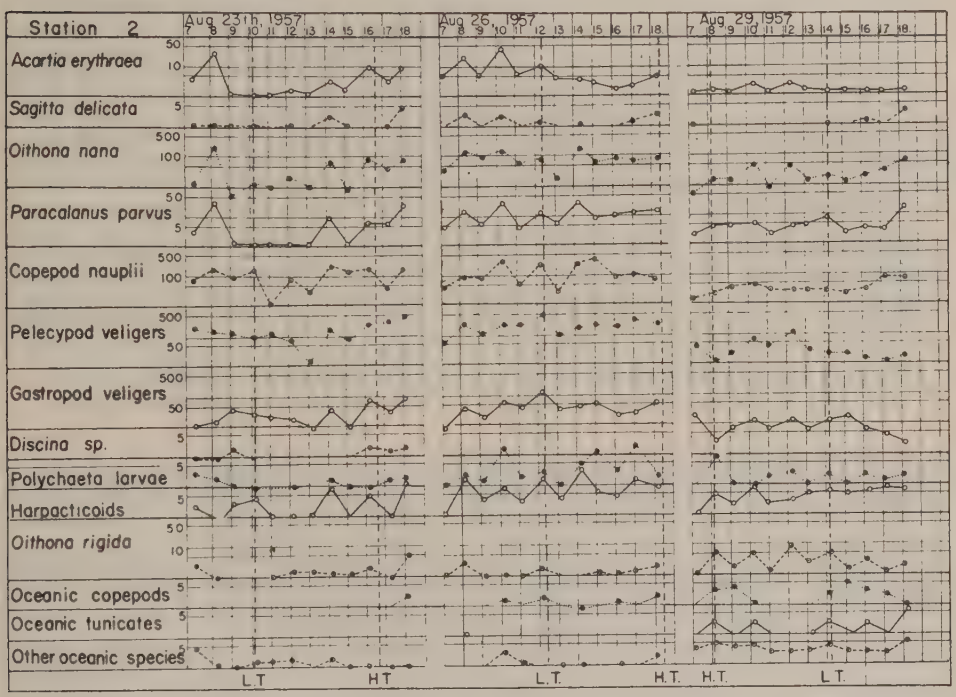

Fig. 6. Hourly fluctuations of the important plankton organisms at St. 2 between August 23, 26, and 29, 1957. The explanation refers to the text.

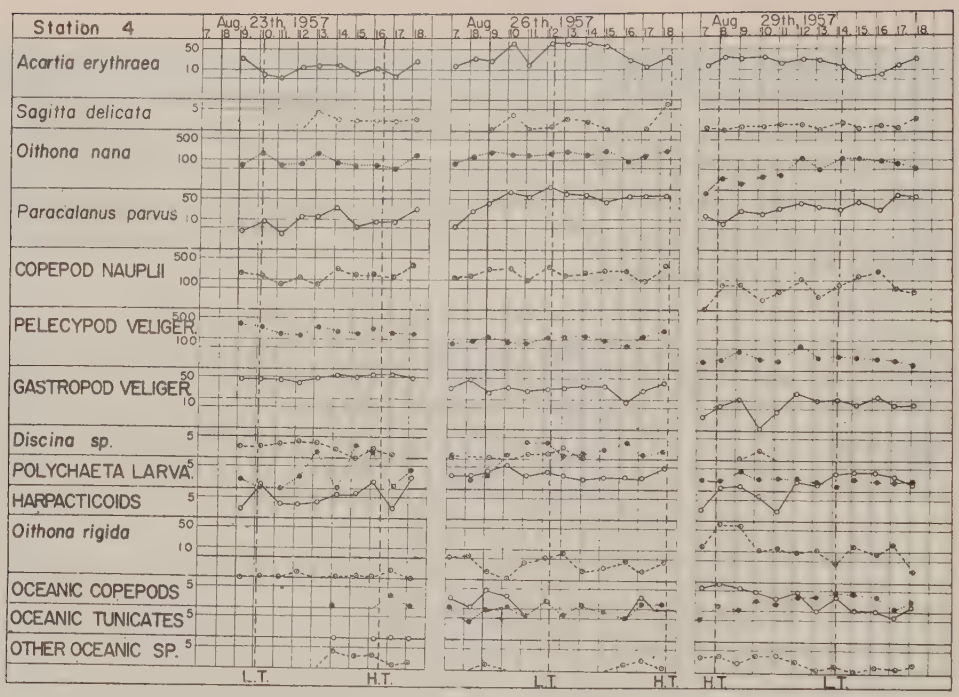

Fig. 7. Hourly fluctuations of the important plankton organisms at St. 4 between August 23, 26, and 29, 1957. The explanation refers to the text.

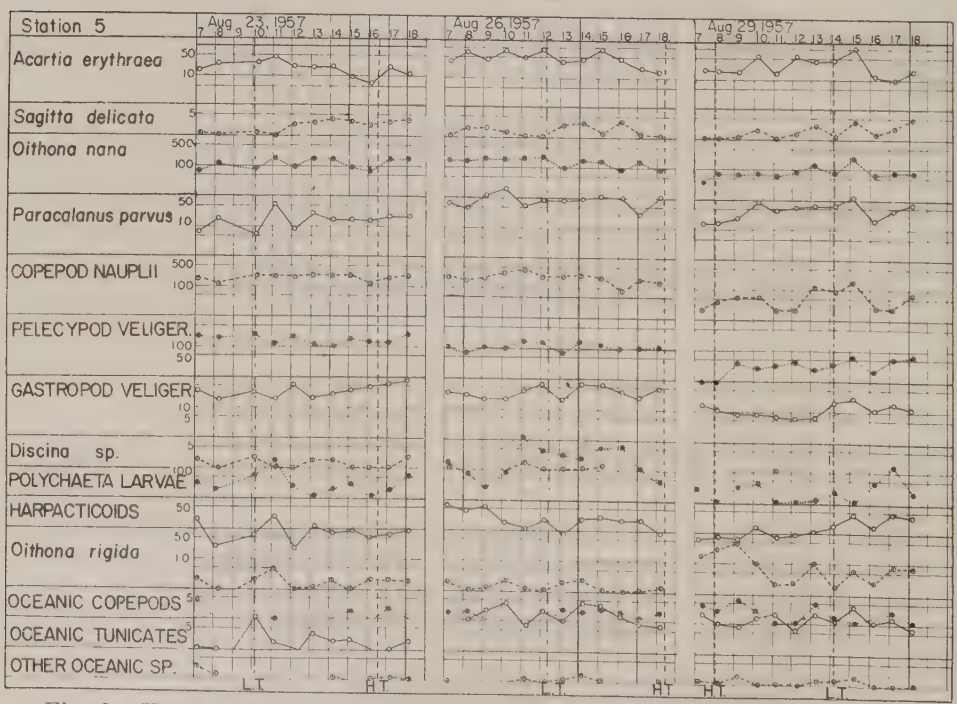

Fig. 8. Hourly fluctuations of the important plankton organisms at St. 5 between August 23, 26, and 29, 1957. The explanation refers to the text.

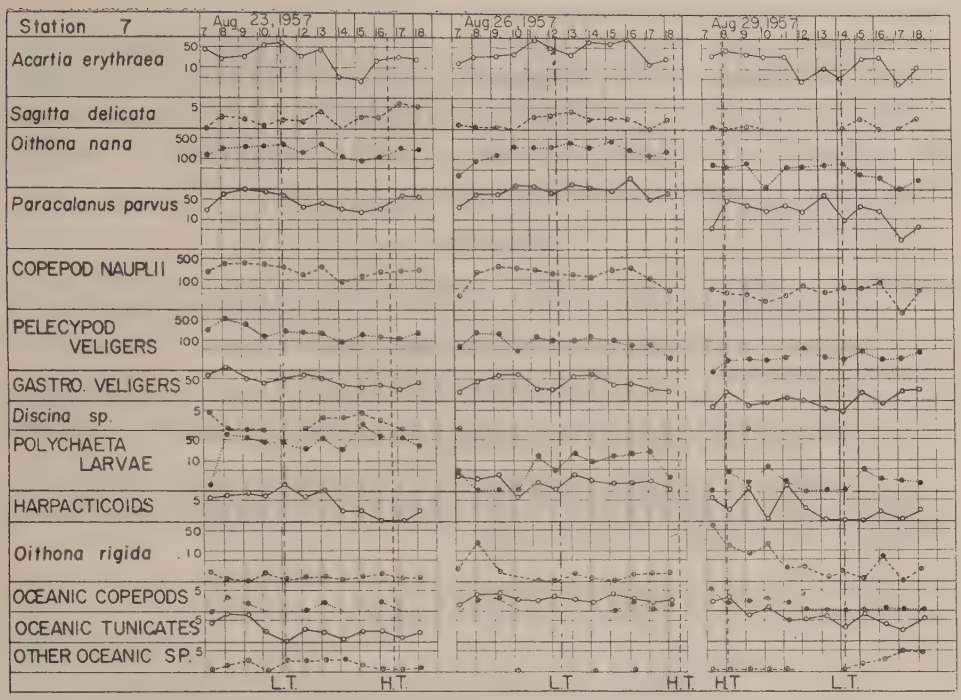

Fig. 9. Hourly fluctuations of the important plankton organisms at St. 7 between August 23, 26 and 29, 1957. The explanation refers to the text.

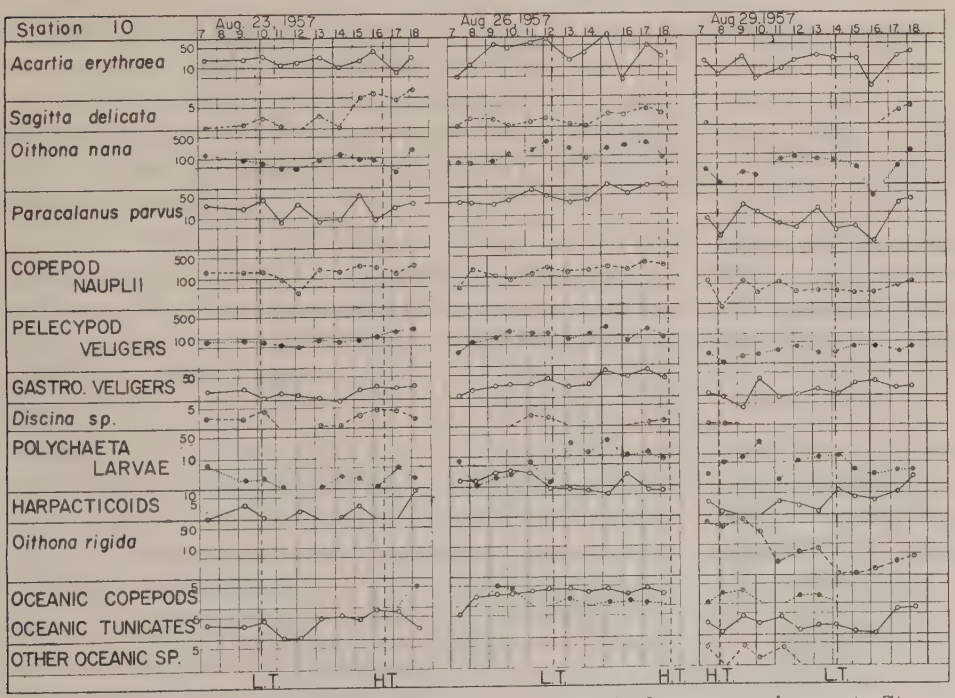

Fig. 10. Hourly fluctuation of the important plankton organisms at St. 10 between August 23, 26, and 29, 1957. The explanation refers to the text.

Along the Line B, the water-mass movement or mixing caused by the daily tidal current is effective enough to produce the fluctuation of populations in the inlet (YAMAZI, 1957), but it is not so strong as to disturb the composition of the inner communities.

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Records of Oceanographic Works
in Japan. (Special Number 3)
October 1959

A STUDY ON THE PRODUCTIVITY OF TANABE BAY
(Part II)

V. Occurrence of the First Stage Phyllosoma Larva of *Panulirus japonicus* (von Siebold) In Tanabe Bay

By

Eiji Harada

(Seto Marine Biological Laboratory, Kyoto University)

Introduction

This work is a part of the survey of Tanabe Bay, which aims to get a profile of its marine productivity and production system.

Japanese spiny lobster, *Panulirus japonicus* (von Siebold), as a dominant inhabitant in the rocky area, is one of the most valuable marine animals, both in quantity and quality, along the coast of southern Japan.

Its larvae in different stages are known to occur in the adjacent waters of this area with some in waters far from the coast.

Many workers have been engaged in the study of the larval stage of Palinurid and Scyllarid lobsters, the larvae of which are quite similar to each other in their appearance in early stages, yet we have had only a little knowledge about their larval life.

As to larval life of Palinurid lobsters, the larvae in the form of the phyllosome are said to take their planktonic life and those metamorphosed into the puerulus stage are acknowledged as the bottom inhabitants (GILCHRIST, 1916; NAKAZAWA, 1917; KINOSHITA, 1931; GURNEY, 1936; LINDBERG, 1955; JOHNSON, 1956; HARADA, 1957). Views of many workers are to attribute offshore life in deep waters to the phyllosoma larvae of advanced stages. GURNEY (1936) says that "it may well be that the earliest stages are passed through fairly rapidly in inshore waters", and regards the late phyllosomes as "apparently confined to the deeper layers". JOHNSON (1956) observed the abundant occurrence of the first stage phyllosomes of *Panulirus interruptus* (Randall) at coastal stations of California and suggested that "the finding of later stages floating above the 140 meter level in waters of depth ranging to several hundred meters and over 300 miles from shallow water showed that at least many of the larvae of our species do not seek the bottom regularly in the phyllosoma stages".

It is, however, still debatable whether the advanced stage phyllosomes must disperse to offshore or they are naturally able to live through and pass into bottom life in the coastal water as in the bay, and where and in what stage the larvae take bottom life. Length of surface planktonic life in the first phyllosoma stage and occurrence of the first stage phyllosome in deep waters should be, in this connection, of considerable importance. These points are also of great importance in considering the improvement of the natural resource of the animal concerned, and, in addition, in considering the qualitative aspect of the productivity of the definite area of the sea. The biological productivity and the production system of the sea are usually discussed from the stand-point of the quantity, namely the biomass, of the phytoplankton, the zooplankton, or the consumers depending upon these, and their interrelations. But if the area be used as inevitable natural habitat, for example, for larval life of certain animals, which appears in the plankton, there arises another value in the productivity of the area to be added upon that derived from the estimation of the plankton as a biomass. The area has its special contribution in sustaining the larvae which will later grow up to the dominant predatory animal of high commercial value, which can not be expectative to be explained when the planktonic larvae are dealt with as the food for the high-level animals in the pyramid of numbers alone.

Materials

In this paper, the author deals with the horizontal and vertical distribution of the first stage phyllosomes of *Panulirus japonicus* in Tanabe Bay, with some references to that out of the bay.

Tanabe Bay, located at the south-west coast of Kii Peninsula, has rocky coast and its vicinity with abundant population of the adult animals of this species. Stations were selected in and out of the bay, where several depths of the horizontal haul of a large plankton net with its mouth of 1 metre in diameter were determined in relation to the depth of the station. The number of the first stage phyllosomes from plankton collections was counted, which was shown in Table 1 as numbers per 1,000 cubic metres of water strained by the net. This work was done in 1957.

Results and Discussion

The first stage phyllosomes occurred in the plankton collection in July and August, but not in October at any depth and at any station. When they were found in the plankton collections, they were more abundant in the deeper layer in most cases. In the vertical collections from the bottom to the surface at Stations S2 and S3 in the night of July 19, 176 and 33 of the first stage phyllosomes per 1,000 cubic metres of water were found respectively, and 36 at Station B1 in the daytime of July 19.

Although the information on the life of phyllosoma larvae of *Panulirus japonicus* obtained by this survey is not sufficient, because of the scarcity of

collections, the first stage phyllosomes of this species seem to be abundant in deep waters of the bay. The first stage phyllosomes may at first spend its early time at the surface (HARADA, 1957) and go down to deep waters even in a bay not far from their freed area, hence there is the possibility that the bottom of a bay may serve as habitat of their larval period.

Table 1. Numbers of the first stage phyllosomes of *Panulirus japonicus* per 1,000 cubic metres of water strained by the large plankton net which was hauled horizontally in each depth.

Station No.	Depth (metre)	July 19 08.50 ~ 13.55	July 19 20.15 ~ 22.45	Aug. 1 08.30 ~ 12.22	Aug. 7 13.05 ~ 13.15	Aug. 10 09.03 ~ 11.47	Aug. 23 09.32 ~ 12.08	Oct. 4 09.47 ~ 12.35	Oct. 10 10.13 ~ 12.02
10	0– 2	—	—	—	—	—	0	0	—
	10–15	—	—	—	—	—	21	0	—
64	0– 2	—	—	—	0	0	0	—	0
	20–30	20	0	88	47	23	35	—	0
92	0– 2	—	—	—	—	46	0	—	0
	15–20	—	—	—	—	0	35	—	0
109	0– 2	0	—	23	—	—	—	0	—
114	3– 5	12	—	—	—	—	—	—	—
	10–15	—	—	0	—	—	—	0	—
B1	0– 2	—	—	0	—	—	—	—	—
	20–25	2	—	0	—	—	—	—	—
S1	0– 2	—	—	—	—	7	0	0	—
	4– 6	—	—	—	—	—	0	—	—
	20–25	—	—	—	—	0	—	0	—
S2	0– 2	—	—	—	—	7	0	0	—
	10–15	—	—	—	—	—	14	0	—
	25–30	—	7	—	—	39	—	0	—
S3	0– 2	—	—	0	—	—	—	0	—
	25–30	—	—	0	—	—	—	0	—

Fig. 1. Map of Tanabe Bay showing stations of hauling.

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Records of Oceanographic Works
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October 1959

A STUDY ON THE PRODUCTIVITY OF TANABE BAY (Part II)

VI. On the Exchange of Water and the Productivity of a Bay with Special Reference to Tanabe Bay (2)

By
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(Geophysical Institute, Kyoto University)

Introduction

The specific gravity at 0°C of sea water (σ_0) obtained from the chlorinity by Knudsen's Tables, is generally different from the specific gravity at 0°C of the same water (σ_0') by direct measurement. The difference $\Delta\sigma_0 \equiv \sigma_0 - \sigma_0'$ was provisionally termed the mass defect of sea water by the present authors. Among physical, chemical and biological effects which give $\Delta\sigma_0$, the fixation of dissolved materials in sea water by living bodies seems to be most effective, because $\Delta\sigma_0$ becomes larger, the longer the sea water moves without mixing with the surrounding waters. The rate of increase of $\Delta\sigma_0$ in a unit time for a given volume of sea water, therefore, indicates the rate of increase of the living bodies in the same water, while the rate of increase of $\Delta\sigma_0$ slows down under constant supply of fresh sea water, though the action of living bodies in the water is invariable. The space distribution of $\Delta\sigma_0$ and its time change will offer, in this sense, a new method of study to the problems of the productivity and the exchange of water in any sea region.

Standing on this view point, the authors observed the tidal change of $\Delta\sigma_0$ of sea water flowing through a section across the bay mouth of Tanabe Bay, a small bay along the southern coast of Japan, facing the Pacific Ocean and discussed the productivity of this bay (HAYAMI et al, 1958). As the water samples used in this study, however, were limited only in the surface layer, they could not discuss the vertical distribution of $\Delta\sigma_0$ in the said bay water. In the present paper, some of the results of observations of the space distribution of $\Delta\sigma_0$ in the bay, as well as the tidal change of $\Delta\sigma_0$ at various depths in the same section with the previous survey already reported across the bay mouth, are outlined.

1. Tidal change of $\Delta\sigma_0$ in the bay mouth

Along the same line AB (Fig. 3) across the bay mouth which was used in the previous survey, five boats were anchored at equal intervals and on board

every boat sea water was sampled at the depth of 0, 5, 10, 15, 20 and 25 m every hour from 8h to 19h, Aug. 11th, 1957. The same amount of five samples taken respectively on board the five boats, at the same level and at the same time, were afterwards mixed and considered as a mean water of each level in the section at the respective time. For these mixed waters σ_0' and Cl were measured and $\Delta\sigma_0$ was calculated from them. The accuracy of determination is ± 0.01 ‰ for Cl and $\pm 2\times10^{-3}$ for $\Delta\sigma_0$, hence the accuracy of $\Delta\sigma_0$ is of the order of $\pm 10\times10^{-3}$. The result is shown in Fig. 1 together with the tidal curve at Mori situating at the bay head, and the correlation of $\Delta\sigma_0$ and Cl is shown

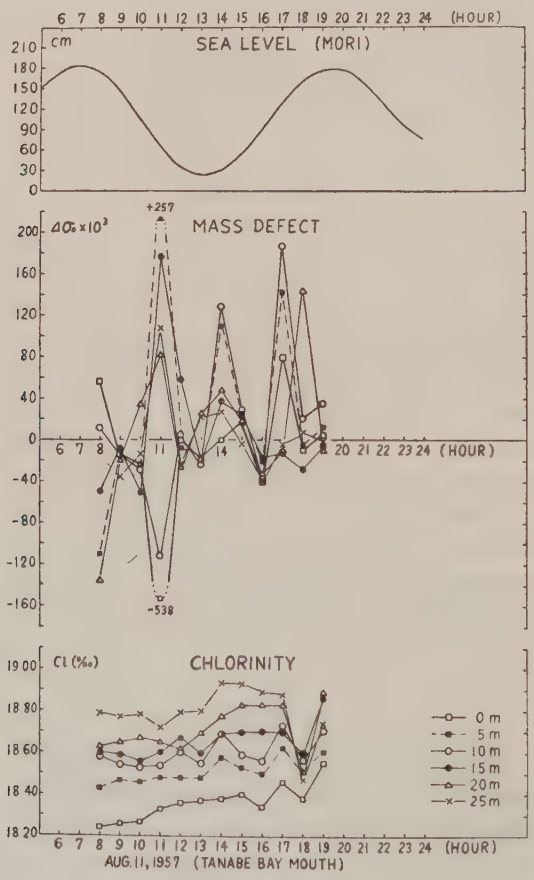

Fig. 1. Tidal variations in mass defect and chlorinity in Tanabe Bay, Aug. 11, 1957.

in Fig. 2. As is seen from these figures, the mass defect $\Delta\sigma_0$ indicates a clear tidal change and it increases at low tide and decreases at high tide as is commonly observed. The tidal change of $\Delta\sigma_0$ is nearly independent of the chlorinity. It is interesting that from 8h to 12h, the tidal changes of $\Delta\sigma_0$ at 0 and 10 m layers are reverse to those of other layers. It is specially worth to note that three maxima of $\Delta\sigma_0$ appear at and around the time of low tide. The time interval

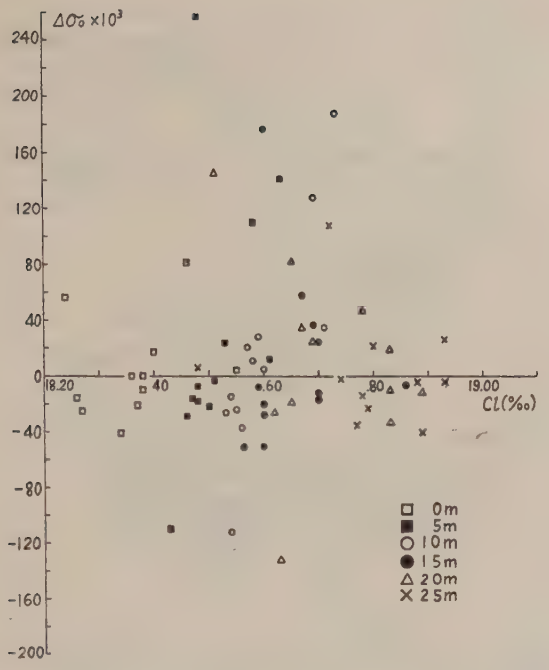

Fig. 2. Correlation between mass defect and chlorinity in Tanabe Bay, Aug. 11, 1957.

of successive maxima is three hours. This peculiar change seems, according to the authors' experience at other places, to be due to eddies of 6 hours in period, which are generated at or around the time of slack water of semi-diurnal tide.

The range of tidal change of $\Delta\sigma_0$ does not vary much for different layers. As the tidal current velocity decreases downwards, the constancy of tidal range means a downward increase of horizontal gradient of $\Delta\sigma_0$ at the bay mouth; in other words, the mass defect of deep water in the bay has a relatively large value in contrast to deep water outside of the bay, indicating that the boundary of both waters is relatively sharp. In the deep layers, accordingly, a slight horizontal displacement of this boundary will result in a large change of tidal range of $\Delta\sigma_0$. The change of $\Delta\sigma_0$ of 25 m level in Fig. 1 seems to indicate this relation.

2. Distribution of $\Delta\sigma_0$ in the bay

At twenty six stations distributed uniformly in the bay, sea water was sampled at the surface layer and at the depths of 5, 10, 15, 20 and 25 m and the mass defect and the chlorinity were determined for them. In order to obtain the space distribution of $\Delta\sigma_0$ in the bay, it is desirable to make a simultaneous observation, but it was practically impossible for the authors to use a sufficient number of survey boats. Their observations were carried out from 9h 20 min to 18h, Aug. 10th, 1957. The position of station and the observa-

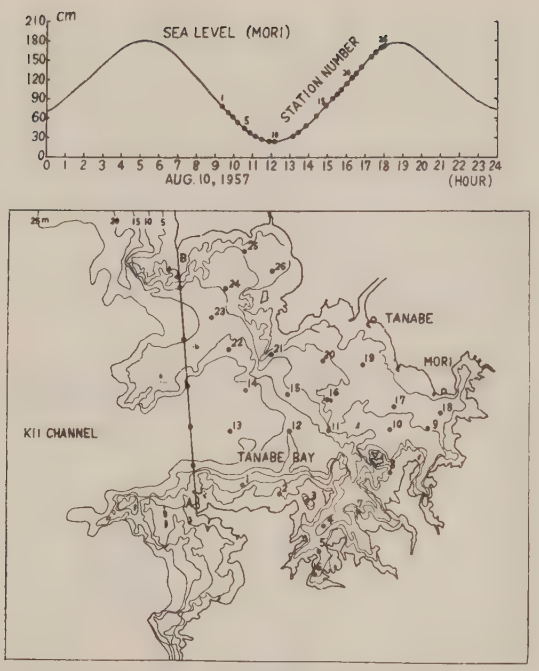

Fig. 3. Location of sampling stations where the figure at each station indicates the number of station in the sequence of observations (lower).
Time of observation and phase of tide at each station (upper).

tion time at each station are shown in Fig. 3. As the depth of the bay is not uniform, the number of samples at each layer are limited by the depth of the bay.

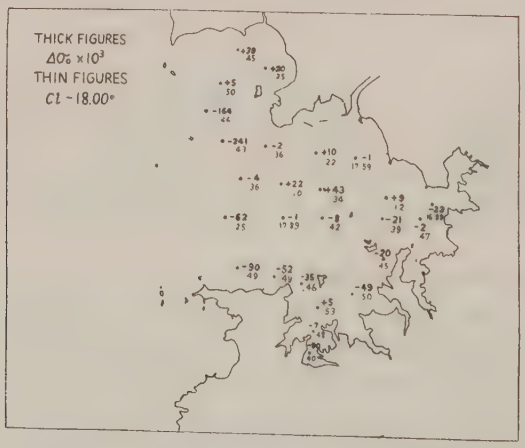

Fig. 4. Distribution of mass defect and chlorinity in Tanabe Bay, Aug. 10, 1957 (the surface).

Fig. 5. Distribution of mass defect and chlorinity in Tanabe Bay, Aug. 10, 1957 (5 m).

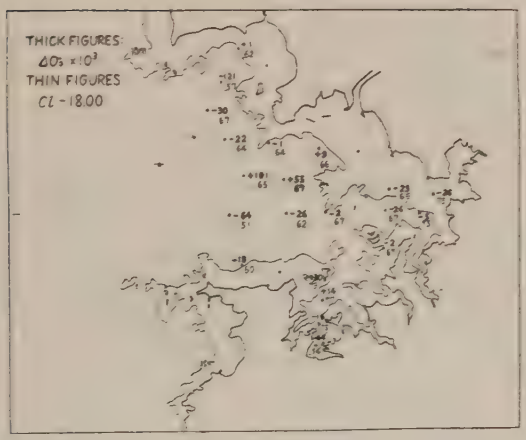

Fig. 6. Distribution of mass defect and chlorinity in Tanabe Bay, Aug. 10, 1957 (10 m).

The result of observations is shown in Figs. 4–9. Though the distributions of $\Delta\sigma_0$ in these figures do not represent a simultaneous pattern, some common features appear in them which seem to give a certain characteristics of the bay with respect to its productivity. The value of $\Delta\sigma_0$ is relatively small in the southern part of the bay, but increases counter-clockwise towards north.

As the value of $\Delta\sigma_0$ indicates to some extent the amount of water exchange with fresh sea water, the above fact seems to show that the amount of water exchange decreases counter-clockwise from the southern part of the bay towards

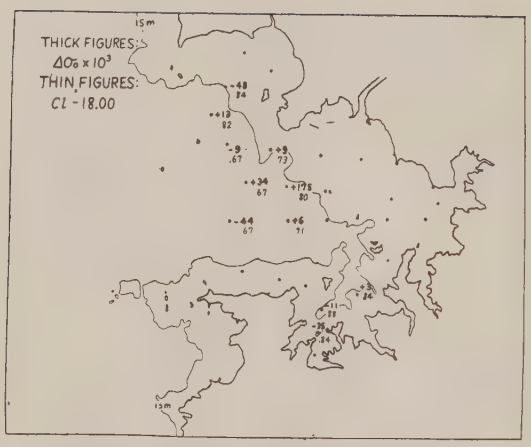

Fig. 7. Distribution of mass defect and chlorinity in Tanabe Bay, Aug. 10, 1957 (15 m).

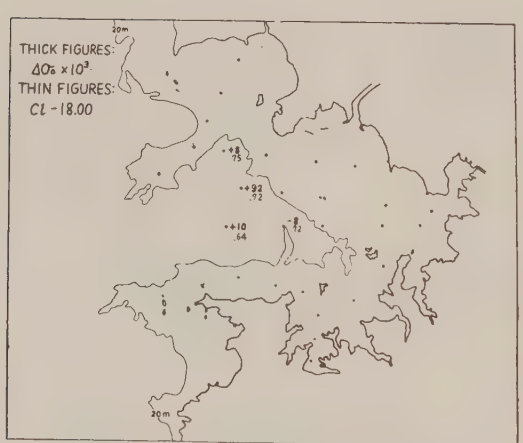

Fig. 8. Distribution of mass defect and chlorinity in Tanabe Bay, Aug. 10, 1957 (20 m).

north, and, in this connection, it is specially remarked that a region of relatively large $\Delta\sigma_0$ occupies the central part of the bay in every layer which suggests the existence of an eddy in this region, in accordance with tidal current observations (NAKAMURA, 1958). A small eddy of the same kind is also seen in the central part of a branch bay openning at the southern part of the bay head.

The vertical distribution of $\Delta\sigma_0$ is different at different stations and apparently seems to be irregular. The mean vertical distribution of all the stations has, however, a regular trend as is shown in the following table.

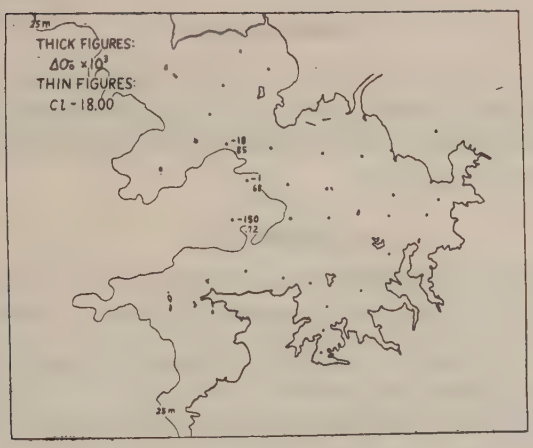

Fig. 9. Distribution of mass defect and chlorinity in Tanabe Bay, Aug. 10, 1957 (25 m).

Depth (m)	0	5	10	15	20	25
$\Delta\sigma_0 \times 10^3$	−27.7	−12.9	−10.6	+18.5	+25.5	−56.3
Cl (‰)	18.28	18.55	18.67	18.77	18.71	18.75

Except the value at the depth of 25 m, $\Delta\sigma_0$ increases with the depth. This increase of $\Delta\sigma_0$ with the depth is partly explained because of a decrease of the amount of water exchange with the depth, though the vertical change of biological activity must be taken into consideration for a complete explanation. As was mentioned in the first report, the mass defect of the bay water is incessantly compensated by the fresh sea water flowing into the bay through tidal mixing. The flux of mass defect flowing out of the bay through a section across the bay mouth is given by $\eta \frac{\delta \Delta\sigma_0}{\delta x}$, where η is mixing coefficient. The range of tidal change of $\Delta\sigma_0$ at the bay mouth is a change of $\Delta\sigma_0$ for $\Delta x = u \cdot T/2$, where u is a mean current velocity and T is the period of tide. As the mixing coefficient η is proportional to $u^2T/2$, the flux varies directly with $u\delta\Delta\sigma_0$. On the other hand, the tidal range of $\Delta\sigma_0$ does not sensibly change with the depth, while current velocity u decreases with the depth. Hence the flux of mass defect decreases with the depth, in other words, the amount of water exchange at the bay mouth decreases with the depth. The abrupt increase of $\Delta\sigma_0$ below the depth of 15 m seems to have connection with the corresponding contraction of the bay below this level which will cause a rapid decrease of current velocity. As to the small value of $\Delta\sigma_0$ at the depth of 25 m, it will be explained by an intrusion of fresh sea water along the bottom as is suggested by the tidal change of $\Delta\sigma_0$ at the bay mouth and the vertical distribution of the chlorinity shown in the above table.

Acknowledgement

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PELECYPOD SHELL REMAINS OF ARIAKE BAY

By

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This report is one of the series dealing with the fauna and flora of Ariake Bay. The collection of the molluscan remains dealt with in this paper was made by the Seikai Regional Fisheries Research Laboratory of Nagasaki in the course of the first scientific fisheries survey of this bay, which was carried out on September 14–18th, 1957. The pelecypod shell remains taken by means of Kamiya's dredge from 33 stations (Fig. 1) consist of 121 species, of which 6 species are new to science. In the bottom material dredged from stations 9, 21, 27 and 28, no determinable shell remains were found. Therefore the remaining 29 stations and their pelecypod species are the objects of this study.

Before going further the writer wishes to express his sincere thanks to Dr. Tokimi Tsujita who was the chief of this survey and to Mr. Yataro Tanaka for his kind cooperation. The writer is also indebted to the Special Committee on Marine Resources in the Japanese National Commission for Unesco for the grant in aid to this work.

A List of the Pelecypod species found in Ariake Bay during the First Scientific Fisheries Survey on Sept. 14–18th, 1957.

Specific Name	Number of Station
1. *Arca boucardi* Jousseaume	10, 13, 14, 15, 20, 32, 33.
2. *Barbatia stearnsi* (Pilsbry)	19, 33.
3. *Nipponarca bistrigata* (Dunker)	1, 6, 10, 12, 26, 33.
4. *Anadara satowi* (Dunker)	1, 2, 3, 4, 6, 7, 10, 12, 15, 16, 18, 19, 20, 22, 23, 26.
5. *Striarca symmetrica* (Reeve)	10, 19, 33.
6. *Striarca olivacea* (Reeve)	4.
7. *Striarca interplicata* (Grabau et King)	1, 15, 16, 17, 26, 29.
8. *Striarca tenebrica* (Reeve)	1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 18, 20, 33.
9. *Oblimopa forskallii* (A. Adams)	18, 19, 22, 26.
10. *Modiolus japonicus* (Oyama)	31.
11. *Modiolus comptus* (Sowerby)	2, 6, 7, 8, 10, 11, 12, 18, 19, 20, 22, 25, 26, 30, 32, 33.
12. *Modiolus metcalfei* (Hanley)	6.
13. *Musculus perfragilis* (Dunker)	2, 6, 7, 22.
14. *Atrina pectinata japonica* (Reeve)	1, 3, 4, 6, 7, 13, 18, 24, 26.

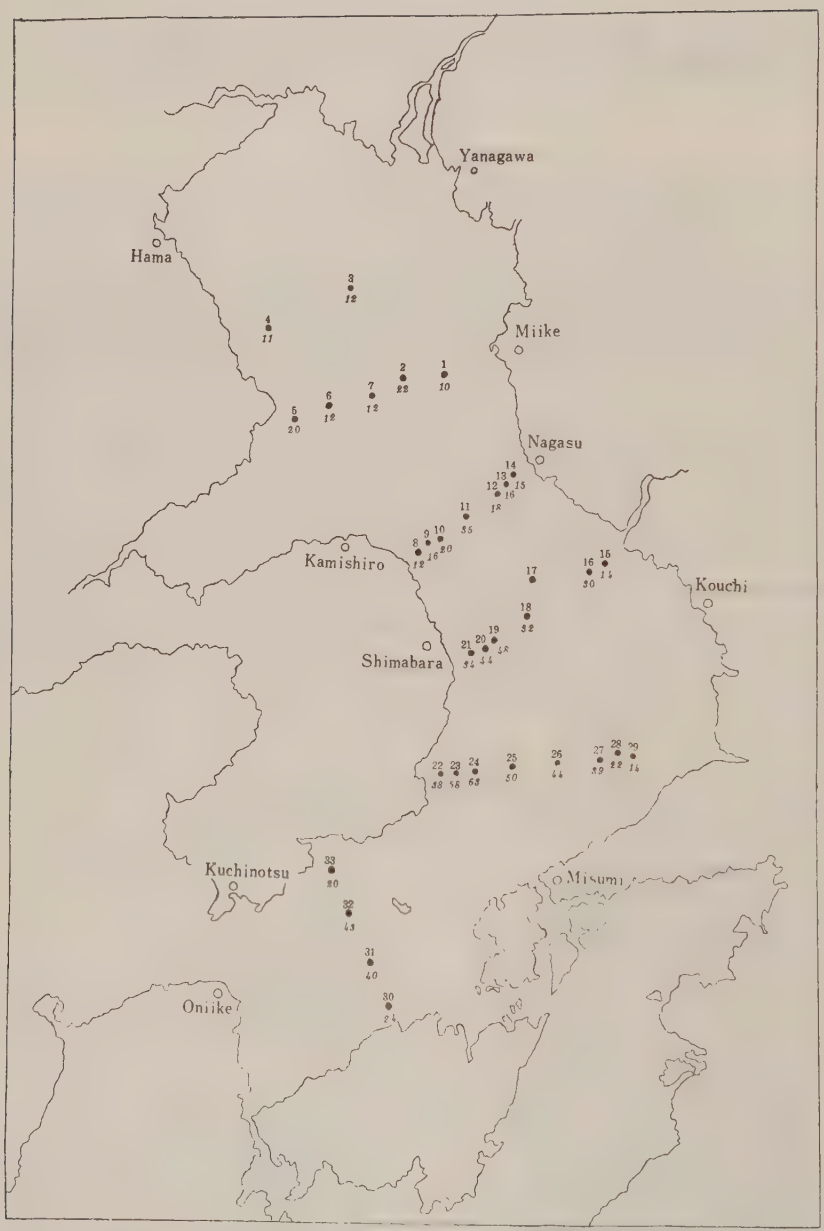

Fig. 1. Map of Ariake Bay showing the stations and their depth in meters.

15. *Plicatula simplex* Gould	10, 30, 31, 33.
16. *Ohlamys irregularis* (Sowerby)	32.
17. *Chlamys nobilis* (Reeve)	20, 32.
18. *Chlamys asperulata* (A. Adams et Reeve)	6, 7, 8, 10, 11, 12, 18, 19, 20, 22, 23, 24, 26, 30, 31, 33.
19. *Chlamys squamata* (Gmelin)	10, 18, 20.
20. *Decatopecten striatus* (Schumacher)	24.
21. *Volachlamys hirasei* (Bavay)	2, 6, 7, 10, 26.
22. *Pecten albicans* (Schroeter)	11, 18, 19, 22, 23, 24, 25, 26.
23. *Spondyrus barbatus* (Reeve)	33.
24. *Limatula strangei* (Sowerby)	33.
25. *Promantellum orientale* (A. Adams et Reeve)	2, 6, 7, 8, 11, 18, 19, 20, 22, 25, 33.
26. *Anomia sinensis* Philippi	6.
27. *Monia umbonata* (Gould)	1, 2, 7, 10, 11, 12, 18, 19, 20, 23, 24, 26, 30, 31, 32, 33.
28. *Dendrostraea imbricata* (Lamarck)	32.
29. 30. *Ostrea denselamellosa* Lischke and *O. futamiensis* Seki	1, 2, 6, 7, 8, 16, 17, 18, 22, 25, 30, 33.
31. 32. *Crassostrea gigas* (Thunberg) and *C. irregularis* (Tokunaga)	1, 2, 3, 6, 7, 8, 10, 11, 17, 18, 19, 22, 23, 24, 25, 32, 33.
33. 2. *Crassatellites nanus* (A. Adams et Reeve)	2, 6, 7, 8, 10, 11, 13, 15, 18, 19, 20, 22, 23, 24, 26, 30, 31, 32, 33.
34. *Cardita leana* Dunker	26, 31, 32, 33.
35. 36. *Venericardia* (*Megacardita*) *ferruginosa* (A. Adams et Reeve) and *V.* (*Pleuromeris*) *pygmaea* Kuroda et Habe	7, 9, 10, 11, 12, 13, 18, 19, 20, 26, 30, 31, 32, 33.
37. *Alvenius ojianus* (Yokoyama)	29.
38. *Anisodonta recluzii* (A. Adams)	1, 10, 12, 18, 20.
39. *Anisodonta stimpsoni* (A. Adams)	26.
40. *Anisodonta gouldi* (A. Adams)	6, 7, 8, 10, 11, 12, 13, 14, 18, 19, 20, 26, 33.
41. *Jouannisiella cumingii* (Hanley)	10, 12, 17, 18.
42. *Jouannisiella lunaris* (Yokoyama)	2, 6, 7, 26.
43. *Jouannisiella tsuchii* sp. nov.	1, 2, 6, 11, 16, 22, 26.
44. *Phlyctiderma japonica* (Pilsbry)	31, 32.
45. *Leptaxinus rotundata* (Yokoyama)	16, 17, 26.
46. *Anodontia stearnsiana* (Oyama)	4, 15.
47. *Ctena divergens* (Philippi)	30.
48. *Pillucina pisidium* (Dunker)	29.
49. *Pillucina yamakawai* (Yokoyama)	16, 17, 26.
50. *Wallucina lamyi Chavan*	6, 26, 32.
51. *Platomysia rugata* Habe	2, 17, 26.
52. *Byssobornia striatissima* (Sowerby)	6, 7.
53. *Melliteryx puncticulata* (Yokoyama)	2.
54. *Fronsella ohshimai* Habe	26.

55. *Borniopsis tsurumaru* gen et sp. nov.	1, 2, 3, 4, 5, 15, 16.
56. *Borniopsis ariakensis* sp. nov.	1, 4, 7, 15.
57. *Kellia tsujitai* sp. nov.	12, 33.
58. *Montacutona tanakai* sp. nov.	22.
59. *Gurvemysia paula* (A. Adams)	24.
60. *Chama reflexa* Reeve	19, 31, 32, 33.
61. *Vasticardium arenicola* (Reeve)	23, 24, 32, 33.
62. *Laevicardium undatopictum* (Pilsbry)	26.
63. *Microcirce gordonis* (Yokoyama)	2, 7, 26.
64. *Pitar affinis* (Gmelin)	25.
65. *Pitar japonica* Kuroda et Kawamoto	1, 2, 6, 7, 11, 12, 18, 22, 23, 24, 26.
66. *Pitar chordata* (Roemer)	18, 26.
67. *Callista chinensis* (Holten)	11, 20.
68. *Sunetta subquadrata* Sowerby	12.
69. *Dosinia angulosa* (Philippi)	6, 7.
70. *Dosinia japonica* (Reeve)	7.
71. *Venus toreuma* (Gould)	32, 33.
72. *Antigona lamellaris* Schumacher	31.
73. *Placamen tiara* (Dillwyn)	25, 26.
74. *Veremolpa minuta* (Yokoyama)	22, 26.
75. *Veremolpa micra* (Pilsbry)	1, 2, 3, 4, 5, 6, 12, 15, 18, 22, 26.
76. *Gomphina neastartoides* (Yokoyama)	33.
77. *Protothaca jedoensis* (Lischke)	10.
78. *Tapes japonica* (Deshayes)	1, 2, 3, 6, 15, 18.
79. *Paphia euglypta* (Philippi)	7, 8, 10, 12, 18, 26, 31.
80. *Paphia undulata* (Born)	1, 3, 4, 5, 15, 16, 17, 29.
81. *Clementia vatheleti* Mabille	22.
82. *Irus metis* (Deshayes)	31.
83. *Mactra sulcataria* Reeve	6, 7, 10, 11, 12, 18, 19, 20, 22, 26, 33.
84. *Mactra ornata* Gray	33.
85. *Mactra angulifera* Reeve	7, 11, 12, 20, 23, 26.
86. *Oxyperas bernardi* (Pilsbry)	10, 11, 18, 19, 20, 23, 24, 25, 26, 30, 31, 32, 33.
87. *Raeta pulchella* (A. Adams et Reeve)	1, 2, 3, 4, 5, 7, 15, 16, 26, 29.
88. *Gari hosoyai* Habe	17.
89. *Gari maculosa* (Lamarck)	10, 20, 32.
90. *Semele zebuensis* (Hanley)	10, 20, 24, 32, 33.
91. *Semele cordiformis* (Holten)	26, 30, 31.
92. *Abrina kanamarui* (Kuroda)	1, 2, 6, 7, 10, 11, 12, 15, 16, 17, 18, 19, 20, 22, 26.
93. *Theora lubrica* Gould	1, 3, 4, 5, 16.
94. *Cadella delta* (Yokoyama)	1, 2, 5, 6, 18, 19.
95. *Cadella narutoensis* sp. nov.	6, 7, 10, 11, 12, 20, 22, 24, 26, 33.
96. *Arcopagia subtruncata* (Hanley)	6, 7, 8, 12, 18, 26.

97.	*Macoma tokyoensis* Makiyama	1, 4.
98.	*Macoma awajiensis* Sowerby	1, 2, 6, 7, 10, 11, 12, 18, 19, 20, 26, 31.
99.	*Macoma praerupta* (Salisbury)	15, 16.
100.	*Semelangulus miyatensis* (Yokoyama)	2, 6, 7, 10, 12, 18, 22, 26.
101.	*Moerella iridescens* (Benson)	1, 2, 4, 26.
102.	*Fabulina minuta* (Lischke)	7, 20, 22, 26.
103.	*Fabulina nitidula* (Dunker)	1, 2, 26.
104.	*Sinonovacula constricta* (Lamarck)	1, 2.
105.	*Culterensis attenuatus* (Dunker)	17, 25.
106.	*Solen gordonis* Yokoyama	10, 18, 20, 24, 32.
107.	*Solen roseomaculatus* Pilsbry	11, 18, 19, 22, 24, 25, 26.
108.	*Solecurtus divaricatus* (Lischke)	6, 18, 26.
109.	*Hiatella orientalis* (Yokoyama)	2, 7, 10, 11, 12, 18, 19, 22, 26, 30, 31, 33.
110.	*Varicorbula bifrons* (A. Adams)	31.
111.	*Varicorbula yokoyamai* Habe	12, 19, 22, 26.
112.	*Anisocorbula scaphoides* (Hind)	31.
113.	*Anisocorbula venusta* (Gould)	6, 7, 10, 11, 18, 19, 20, 22, 30, 31, 33.
114.	*Mya japonica* Jay	18.
115.	*Cryptomya busoensis* Yokoyama	10.
116.	*Gastrochaena grandis* (Deshayes)	19.
117.	*Barnea manilensis inornata* (Pilsbry)	10, 12, 13, 18, 30, 33.
118.	*Barnea japonica* (Yokoyama)	1, 2, 4, 26.
119.	*Pandora otukai* Habe	18.
120.	*Myadora fluctuosa* Gould	2, 6, 12, 15, 16, 17, 18, 26.
121.	*Plectodon ligula* (Yokoyama)	26.

General Remarks on Pelecypod Shell Remains

The inner area of Ariake Bay covered by stations 1–5 of muddy bottom is represented by the type of pelecypod shell remains of *Theora lubrica-Paphia undulata-Raeta pulchella-Veremolpa micra* assemblage, which is shown typically at Station 3. The two stations, namely Stations 15 and 16, near the mouth of Kikuchi River which empties into the bay on its east coast, resemble to those of the inner area in the composition of their shell remains, being represented by *Paphia undulata-Raeta pulchella-Myadora fluctuosa-Abrina kanamarui* assemblage, a modification of the former assemblage. Station 29 near the mouth of Midori River in the south-east area of this bay differs somewhat from above stations being dominated by *Alvenius ojianus,* which is accompanied by a small number of shell remains of *Pillucina pisidium, Paphia undulata, Raeta pulchella* and *Striarca interplicata.*

The central area of the bay, to which stations 6–12, 18–20 and 26 of fine sand or coarse sand bottoms belong, has the assemblage of *Modiolus comptus-Crassatellites nanus-Chlamys asperulata,* which is usually accompanied by a large number of remains of four kinds of oyster, namely *Ostrea deselamellosa,*

O. futamiensis, *Crassostrea gigas* and *C. irregularis*. Other remarkable associated species of this assemblage are *Abrina kanamarui*, *Monia umbonata*, *Anisodonta gouldi* and *Myadora fluctuosa*.

The gravel bottom near the entrance of the bay, i.e. stations 23–25 and 30–33, is characterized by *Oxyperas bernardi-Monia umbonata-Chlamys asperulata-Crassatellites nanus* assemblage with two oyster species of *Ostrea futamiensis* and *Crassostrea irregularis*.

Besides 121 pelecypod species, 3 scaphopod and about 90 gastropod species were collected from 29 stations of this bay.

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STANDING OSCILLATION OF BAY WATER INDUCED BY CURRENTS

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Abstract:— A model experiment was carried out on the standing oscillation of water in a bay induced by tidal or oceanic currents rushing past the bay laterally. A discussion was made on the mechanism of excitation of this standing oscillation based on the theory of Kármán vortices. It was shown that a relation $\frac{l}{u}=T$ exists among the period T of the standing oscillation, the mean distance l of any two adjoining Kármán vortices lying on one side of the jet of current, and the velocity of travel u of the system of vortices.

1. Introduction

It is a well-known fact that when a jet of air is blown into the mouthpiece of an organ pipe, a tone of definite pitch is produced because there is a standing oscillation of the air column in the pipe, and the analogous phenomenon may be expected to happen in case of liquids. Thus, a tidal or oceanic current

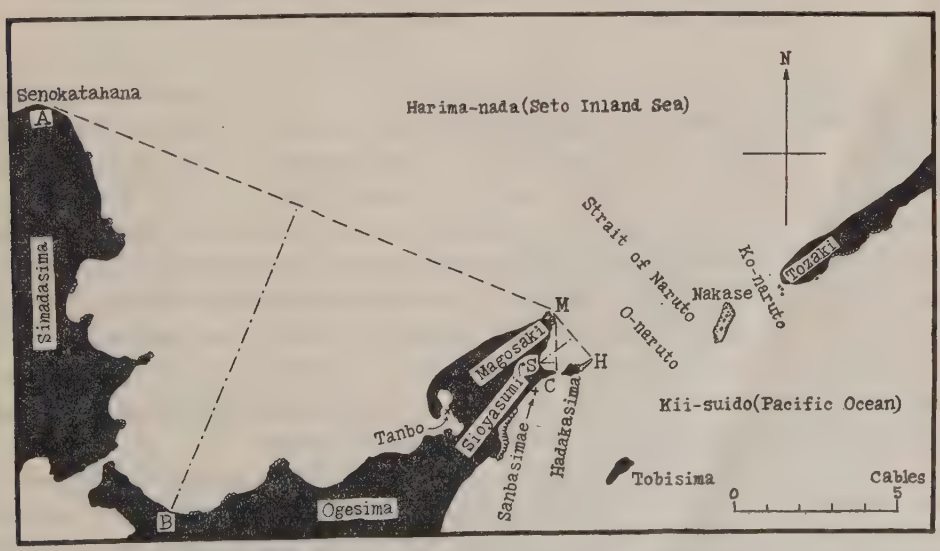

Fig. 1. Map of the Strait of Naruto and its vicinity.

rushing past a bay laterally may become a source of excitation of a standing oscillation of water (secondary undulations of tides) in the bay.[1)2)]

About fifty years ago, H. Nagaoka[3)] suggested the possibility that the Kuroshio current is a source of the long waves often observed on our coasts,

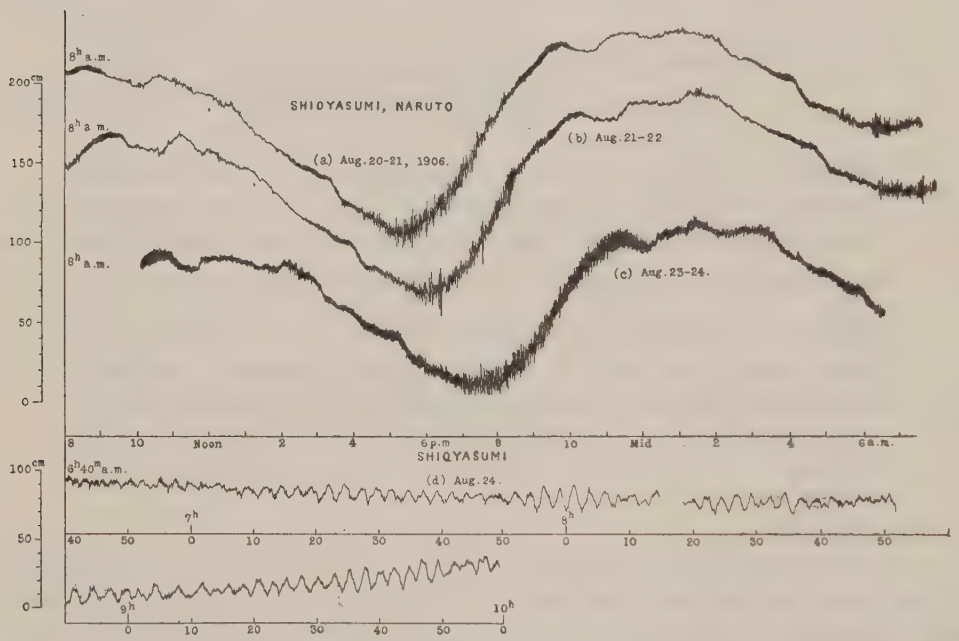

Fig. 2. Conspicuous undulations of about 2.5 min period appearing in the tidal records at Shioyasumi. (After K. Honda, T. Terada and others, 1908).

and from 1903 to 1906 systematic observations of the secondary undulations in bays along the coast of this country were carried out by K. Honda, T. Terada and others.[4)] From their observations a good example of the above view on a small scale was found at the Strait of Naruto (Fig. 1). Fig. 2 shows the mareograms at Shioyasumi on the western coast of the strait obtained by these observers. Looking at this figure we can recognize that, as they have already pointed out, as the current gains in its velocity, a regular undulation of about 2.5 min period becomes gradually conspicuous and attains a maximum amplitude of about 18 cm, and then gradually decreases in amplitude with the diminishing velocity of the current (Fig. 2d). In the records shown in Fig. 2a-c, the thickly zigzagged portions indicate the existence of such waves.

It can be easily seen that the oscillation of 2.5 min period corresponds to the proper oscillation of Shioyasumi Bay (a small semi-circular inlet between Cape Magosaki and Hadakashima Island, Fig. 1), if we calculate the period T of the secondary undulation by the formula:

$$T=\frac{4L}{\sqrt{gh}}, \qquad (1)$$

where L and h represent the length and the mean depth of the bay, respectively, and g the acceleration due to gravity.

As seen in Fig. 1 there are three possible modes of oscillation, namely: (1) standing oscillation of water in the region MSH having its node of vertical motion at MH, (2) the standing oscillation in the region MSC having its node of vertical motion at MC, or (3) the standing oscillation in the region ABM having its node of vertical motion at AM.

In case of (1), L=180 m, h=3.0 m, and hence T=2.2 min, which is in good accord with the observed period of 2.5 min.

On the other hand, in case of (2), L=73 m, h=1.5 m, accordingly T=1.3 min, which is too small in comparison with the observed value.

In case of (3), L=1,467 m, h=34 m, and hence T=5.4 min, which is too large in comparison with the observed value.

Thus, we may conclude that the above-mentioned oscillation of 2.5 min period corresponds to the standing oscillation of Shioyasumi Bay MSH with MH as the mouth-line.*

The above conclusion seems to be confirmed by the following fact as well. Fig. 3 shows an example of simultaneous recordings recently made by the authors[5] with portable tide gauges at three stations Shioyasumi, Tanbo and Sanbashimae (Fig. 1). From this figure we can recognize that, while at Shioyasumi conspicuous undulations of about 2.5 min period occur at the definite

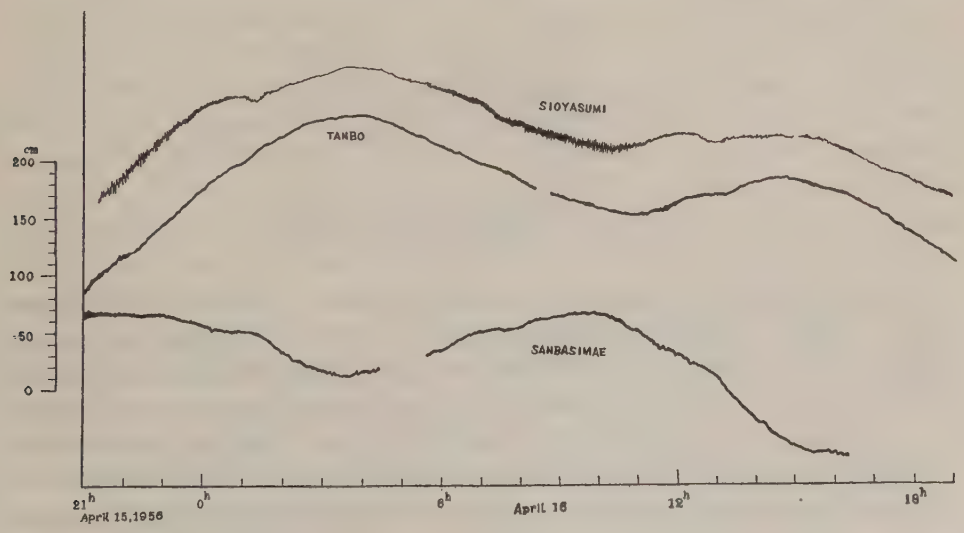

Fig. 3. An example of simultaneous recordings with tide gauges at Shioyasumi, Tanbo and Sanbashimae.

* The gap (the part indicated by C in Fig. 1) between Ogeshima and Hadakashima Islands is so narrow and shallow that it almost disappears at the time of low water.

tidal stages (namely from about the time of LLW to the time a little earlier than that of HHW and about the time of HLW), as in the case of Fig. 2, such undulations scarcely occur at the other two stations fronting on Harimanada and Kii-suido. These facts indicate that the above undulations are proper to Shioyasumi Bay.

2. The Mechanism of Excitation of the Undulations

We now consider the mechanism by which such regular undulations are excited by tidal or oceanic currents. It is a well-established fact that when a jet of current flows out into a wider area through a narrow opening, eddies or vortices are formed along the surface of discontinuity of the edges of the current. And two kinds of configuration of the vortices are possible, *viz.* (1) symmetrical vortices (Fig. 4A) and (2) unsymmetrical vortices (Fig. 4B). According to theory and experiments[6], the symmetrical arrangement of vortices such as shown in (A) is unstable, and this is possible only when the current is very weak. When the current becomes stronger, the arrangement of vortices becomes unsymmetrical as is shown in (B). Thus the current tends to meander or swing horizontally.

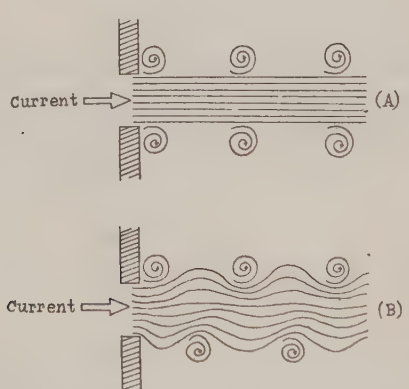

Fig. 4. Symmetrical and unsymmetrical arrangements of vortices.

The frequency N of the swing is given by $Nl=u$, where l is the distance between any two successive vortices lying on one side of the jet and may be regarded as a function of the breadth of the opening, *etc.*; u is the velocity of the vortices and may be regarded as a function of the velocity of the current.

Now, since the two oscillating systems, a jet and a bay, may be considered to constitute together a coupled system, when the period of the swing of the jet comes near to the natural period of oscillation of the bay water, it appears that conspicuous and regular undulations must be excited in the bay.

3. Experiments

In order to verify the above theory, the following experiments were carried out.

(*I*) *Experimental apparatus*

Fig. 5 is a photograph showing the general veiw of the experimental apparatus, and Fig. 6 is its shematic diagram.

Inside a circular zinc tank T, with inside diameter 120 cm and depth 25 cm, there is a composite model CB, (zinc), consisting of an arcuate canal C, of length 40 cm and width 6 cm and a rectangular bay B, with length 10 cm and breadth 5 cm attached to the end of the canal. The bay is attached to the canal in such a way that the axes of the two are perpendicular to each other, and furthermore the end of the canal opposite that at which the bay is attached spreads out in the shape of a funnel. The height of the side walls of the above-mentioned canal-bay is 10 cm. G is a current-generator placed at a distance of about 30 cm from the upstream end of the canal; its principal part is a paddle wheel with twelve rectangular brass plates (each 10 cm long, 6 cm wide and 1.3 mm thick) attached radially about a horizontal shaft at equal intervals of 30°. The horizontal shaft of the wheel is connected with the shaft of an AC electric motor of 1/20 HP by a solid endless rubber belt, and is made to rotate uniformly. A variable transformer (slidac) of 3 A capacity is inserted in the electric circuit so that the speed of rotation of the electric motor may be varied. The arrow drawn in the canal C in Fig. 6 represents the direction in which the current flows. Thus, the jet of current discharged from the canal flows in a direction perpendicular to the axis of the bay at its mouth. A is an oval framework with vertical side wall, and the water inside is almost completely shut off from the water outside. The ends of the side walls of the canal C which spread out in the shape of a funnel are joined to the side walls of the framework A and the tank T at K_1 and K_2, respectively. The aim of the framework A is, on the one hand, to prevent the current and other disturbances produced by the current-generator G from spreading to the bay B through a course other than the canal C, and on the other hand to lengthen the effective length of the waterway and thus stabilize the circulation of water as much as possible. The shortest distance from the mouth of the bay model to the side wall of the framework A is about 30 cm. F_1, F_2, F_3 are filters inserted in the canal C near its upstream end (in some cases only one or two filters were used); the aim of these filters is primarily to get rid of the eddies from the current produced by the current-generator G, and thus make the stream flowing through the canal C into a quasi-stream-line flow which is uniform and steady as far as possible; but at the same time to permit a moderate adjustment of the speed of the current by changing the number or combination of these filters.

The recording of the oscillation of bay water was made on a smoked paper (wound around a rotating drum) by means of an aluminium vane with a pivot and a pen as shown in Fig. 6.

(*II*) *Preliminary experiments*

Before proceeding to the experiment proper, some preliminary measurements were carried out as follows.

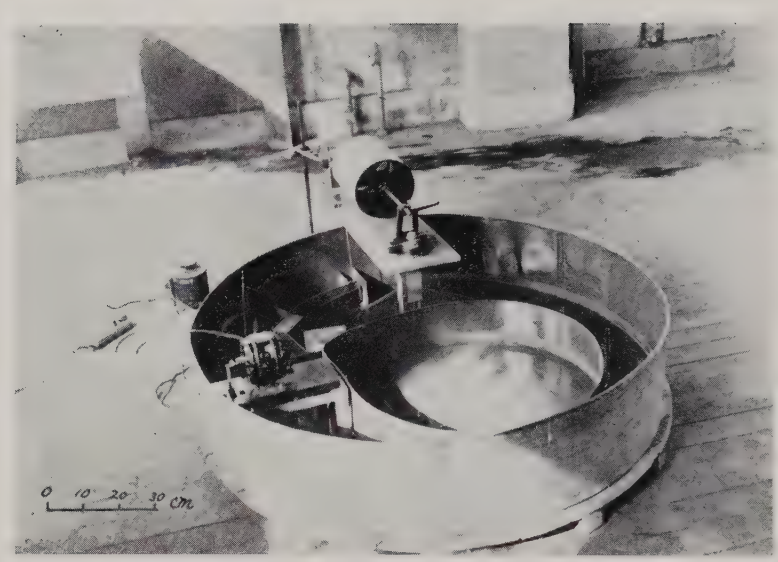

Fig. 5. General view of the experimental apparatus.

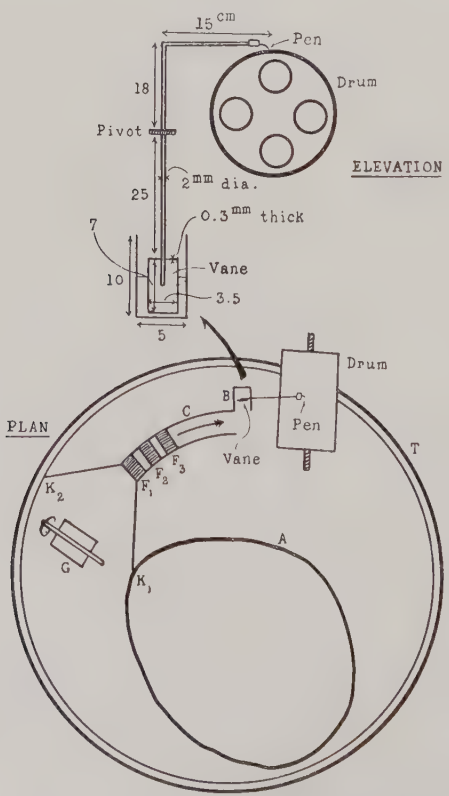

Fig. 6. Schematical diagram of the experimental apparatus.

In the first place, it was necessary to see if the recording pen recorded faithfully the oscillation of bay water. For this purpose water was poured into the circular tank T to a depth of 5 cm, and aluminium powder was spread over the surface of the water. The waves produced by flapping a thin zinc plate with an appropriate period were sent towards the bay model; the oscillation of bay water thus produced and the movement of the vane were observed simultaneously. It was found that the movement of the vane and that of bay water are practically the same. This is due to the fact that the vane is very light and the friction at the pivot and the pen is very small.

Fig. 7 shows some consecutive photographs taken with a 16-mm motion picture camera (16 frames/sec) in order to see the movements of the vane and bay water in the above case. In each of these photographs the square image seen on the right-hand side of the vane is the image of a small square sheet of paper set afloat on the surface of the water. From these photographs the successive positions (distances from the recess of the bay model) of the upper margin of the vane and of the center of the piece of paper were measured, and were plotted in a diagram shown in Fig. 8, where the abscissa represents the frame number of the photographs, and the ordinate the distances mentioned above converted into actual sizes. In the present case, since the speed of the motion picture camera is 16 frames/sec, it follows that 16 divisions on the axis of abscissa correspond to one second. As seen from this figure also, the vane and the sheet of paper move with the same period and phase, and scarcely any relative displacement can be seen between them.

In addition the following two experiments were carried out to insure accuracy; namely, the experiments of free oscillations of the vane in air and in water. In the first place, the tank T was emptied of water, and the vane suspended in air as shown in Fig. 6 was first displaced by hand horizontally by about 5 cm at its lower end from its equilibrium position*, and then released. The resulting oscillation of the vane is shown in Fig. 9. As seen from this figure the vane makes a rather slowly decaying oscillation whose "damping ratio" is about 1.3 with a period of 1.2 seconds; in other words, the vane repeats

Fig. 7. Photographic observations of the movements of the vane and bay water.

* The corresponding displacement at the recording pen is about 3 cm.

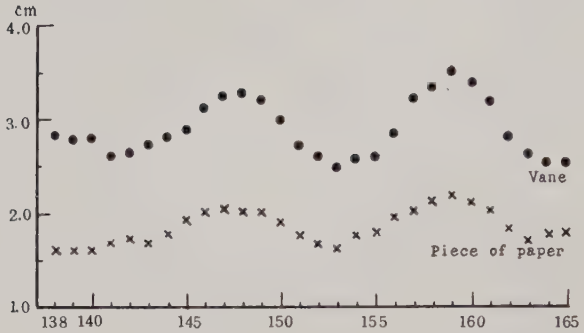

Fig. 8. Time-variations of the distance of the upper margin of the vane and of the center of the square sheet of paper measured from the recess of the bay model.

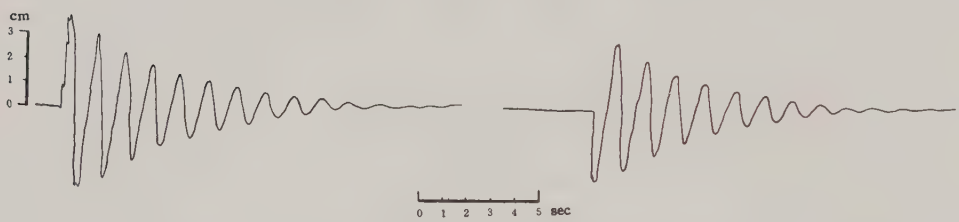

Fig. 9. Some examples of records of the damped oscillation of the vane in air.

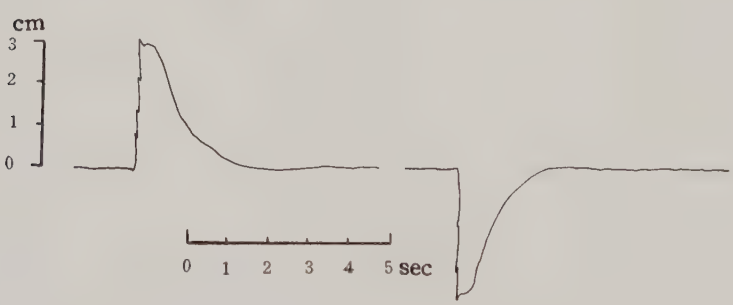

Fig. 10. Some examples of records of the damped oscillation of the vane in still water.

seven or eight complete oscillations till the time when its amplitude of oscillation decreases to 1/10 of the initial value, taking 8–10 seconds. This shows that the frictions at the pivot and the recording pen as well as the resistance of air acting on the vane are very small, though the vane is very light and hence of small inertia.

Next the tank T was again filled with water up to the depth of 5 cm, and after the vane was displaced by hand horizontally in still water by some amount (about 5 cm from its equilibrium position as in the preceding case) it was released. The subsequent motion of the vane is as shown in Fig. 10. As seen

from this figure the vane does not show any oscillation at all, but instead demonstrates the phenomenon of "over-damping". This shows that the free oscillation of the vane itself is almost completely checked owing to the resistance of water, although the frictions at the pivot and the pen are very small. Thus it appears that relative motions can hardly occur between the vane and bay water.

(*III*) *Method of measurement of the velocity of the current*

In order to measure the velocity of the current, three methods were adopted as follows:

(*a*) *Method 1.* This method consists in measuring with a stop watch the time taken by a small piece of woolen yarn set afloat on the surface of water to run through a definite distance (usually 15 cm). By this method we can only obtain an approximate value of the mean velocity of the current for this definite distance.

(*b*) *Method 2.* In this method a simple current-velocity measuring device using a pendulum or a vane such as shown in Fig. 11 was used. A is a pendulum (or a vane) about 40 cm long with an iron sphere having a diameter of 10 mm (or an aluminium plate 11.0 mm long, 8.5 mm wide and 0.3 mm thick) attached to the lower end (B) of a slender and hollow aluminium rod as the bob, the upper end (C) of the rod forming a pointer indicating the slope angle of the pendulum. D is a pivot with a hair spring

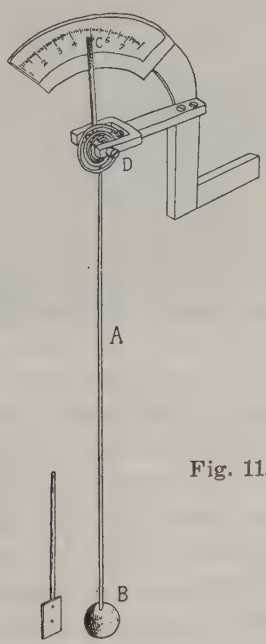

Fig. 11. A simple current-velocity mersuring device using a pendulum or a vane.

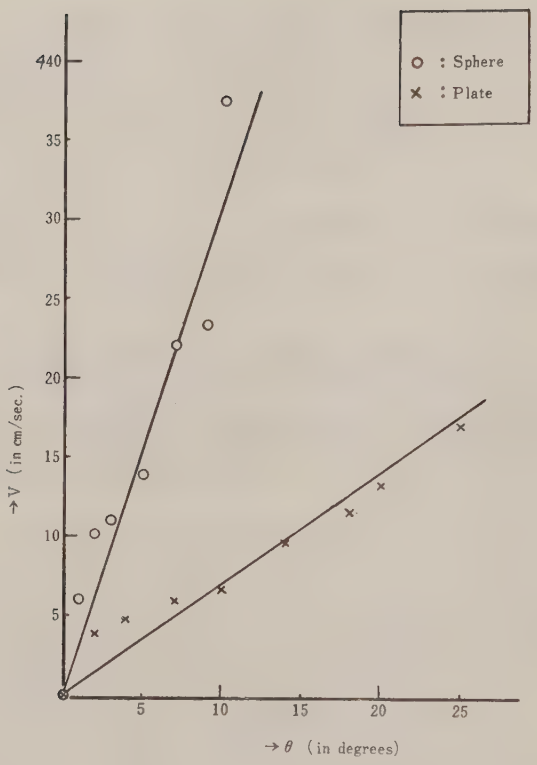

Fig. 12. Relation between the velocity of current, V, and the slope angle of the pendulum, θ.

attached concentrically, which is devised so that when the pendulum rod is deflected a force of restitution appears in the hair spring.

Now, let V be the velocity of the current, and θ the slope angle of the pendulum produced thereby, then $V=f(\theta)$, where $f(\theta)$ is an increasing function of θ.

In Fig. 12 values of θ for various values of V (measured by Method 1) are plotted. The points marked with ○ correspond to the case of the pendulum with the spherical iron bob and those marked with × to the case of the pendulum or vane with the rectangular aluminium plate. The curves in the figure were drawn by free hand so as to represent these points. From Fig. 12 we can find the value of V for any value of θ. When the current is very weak and θ is a small angle such as 3°–4° or less, the value of the current speed estimated from the curves of this figure may have a moderately large relative error, but when θ is larger than 5°–6°, the relative error of this value seems to be small.

(*c*) *Method 3.* This method measures current velocity by photographs of the movements of particles of aluminium powder and some small pieces of

woolen yarn scattered on the surface of the water, as they are carried along by the current. A 35-mm camera (Leica) was used for this purpose. Let δ be the length of the image of a particle of aluminium powder or a piece of woolen yarn appearing on a frame of photograph, and τ the time of its exposure; then the velocity of current at each point on the surface of water is obtained from the value of δ/τ there. In order that the length δ may be measured conveniently, a scale is set in the tank T at the height of water level (Figs. 13 and 14).

Fig. 13. Movements of particles of aluminium powder on the surface of water accompanying the current.

Fig. 14. Movements of particles of aluminium powder and pieces of woolen yarn on the surface of water accompanying the current. A thick white line-segment which is seen on the lower right of the photograph and near the upper right of the scale, is the image of one of the pieces of woolen yarn mentioned above.

The exposure time τ is known from the adopted shutter speed of the camera only roughly, but a more accurate value was found by the following method.

A circular disc made of cardboard with its sectorial part of central angle θ_0 ($=5°$) painted white and the remaining part black as shown in Fig. 15a

was placed on the turntable of an electric gramophone whose speed of rotation was accurately known in advance by using a stroboscope, and was made to rotate with the turntable. This was photographed by releasing the shutter with a designated shutter speed. Fig. 15b shows an example of such a photograph, the designated shutter speed being 1/20 sec. Let θ be the angle of the image of the circular disc which remains white during the duration of the exposure,

Fig. 15a. Diagram of the circular disc used for determining the accurate value of the exposure time of the camera.

Fig. 15b. The circular disc in rotation.

then the net angle of rotation of the disc during this time is θ-θ_0, and hence the actual time of exposure is given by $(\theta-\theta_0)\Big/\left(\frac{360°\,n}{60\,\text{sec}}\right)$, where n represents the number of rotations of the turntable per minute.

In the case of our electric gramophone $n=85$, and θ averaged about 27.5°, when the shutter was released at the designated shutter speed of 1/20 sec ($=50\times10^{-3}$ sec). Therefore, it follows that the real value of the time of exposure τ was $(27.5°-5°)\Big/\left(\frac{360°\times85}{60\,\text{sec}}\right)=44.2\times10^{-3}$ sec instead of 1/20 sec.

(IV) Process of experiment and the result

The experiment was carried out from May till August 1954 in the Oceanographical Laboratory, Meteorological Research Institute, Tokyo.

In the first place, the canal-bay model CB and the current-generator G mentioned in paragraph (I) were set up in the positions shown in Fig. 6, and the tank T was filled with water to such a depth that the water depth h of the bay model became 4.0 cm. (The length L and the breadth b of the bay model are 10 cm and 5 cm, respectively.)

The filters F_1, F_2, F_3 were inserted in the canal model C near its upstream end, and aluminium powder was scattered on the surface of the water, and then the current-generator G was rotated. In order to see if any standing oscillation of water is caused in the bay model by a steady current of a certain strength,

the velocity of the current was changed by varying the speed of rotation of the wheel of the current-generator by moving the index of the slidac and also by changing the number or combination of the filters. It was observed that conspicuous and regular oscillations occurred in the bay model when the current attained an appropriate strength. When the current was of low velocity such as 4–5 cm/sec or less, scarcely any oscillation occurred in the bay; but when the speed of the current exceeded 6–7 cm/sec, oscillations generally occurred in some measure; and when the speed of the current was of the extent of 10–20 cm/sec, vigorous and regular oscillations occurred.

Figs. 16a, b and c give some examples of records showing such conspicuous oscillations, where the corresponding current velocities, (which were determined by the method explained in Method 2 of Paragraph (III)), were about 13, 13 and 10 cm/sec, respectively.

Here a question may arise as to whether the current is really steady when it is flowing in the canal or before it is discharged as a jet of water rushing

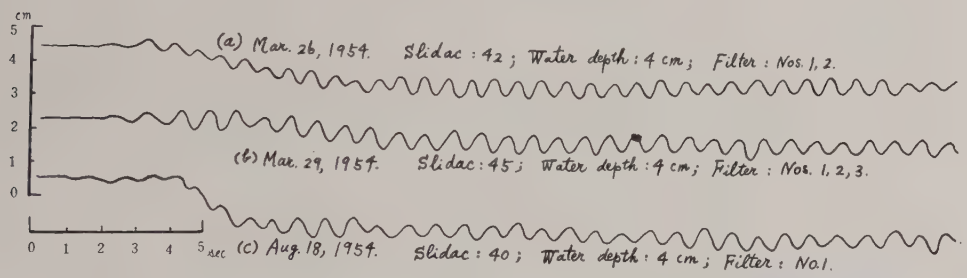
cm
5
4
3
2
1
0
(a) Mar. 26, 1954. Slidac : 42 ; Water depth : 4 cm ; Filter : Nos. 1, 2.
(b) Mar. 29, 1954. Slidac : 45 ; Water depth : 4 cm ; Filter : Nos. 1, 2, 3.
(c) Aug. 18, 1954. Slidac : 40 ; Water depth : 4 cm ; Filter : No. 1.
0 1 2 3 4 5 sec

Fig. 16. Some examples of records showing conspicuous oscillations of bay water.

past the bay; as far as could be known from the observation of the slope angle of the pendulum of the current-measuring device, the original current itself was practically steady. For instance, in the case of the experiment of Fig. 16a, the movement of the index of the pendulum (the vane with small aluminium plate attached to its lower end) was observed with the eye, and at the same time was photographed with a 16-mm motion picture camera (repetition rate: 12 frames/sec; time of exposure of each frame: 1/50 sec); a part of this film is reproduced in Fig. 17. Fig. 18 shows the positions of the index read from this film plotted on a diagram. The horizontal line near the middle represents the equilibrium position (51°) of the pendulum, that is, the position of the index of the pendulum in case there is no current. As seen in this figure, the pendulum is almost at rest sloping with an angle of about 18° from its equilibrium position without showing any regular oscillation.*

* A minute fluctuation in the slope angle of the pendulum which is seen in Fig. 17 seems to be chiefly due to the tremor of the pendulum caused by the wake behind its vane.

Fig. 17. A part of the film taken of the movement of the index of the current-measuring device.

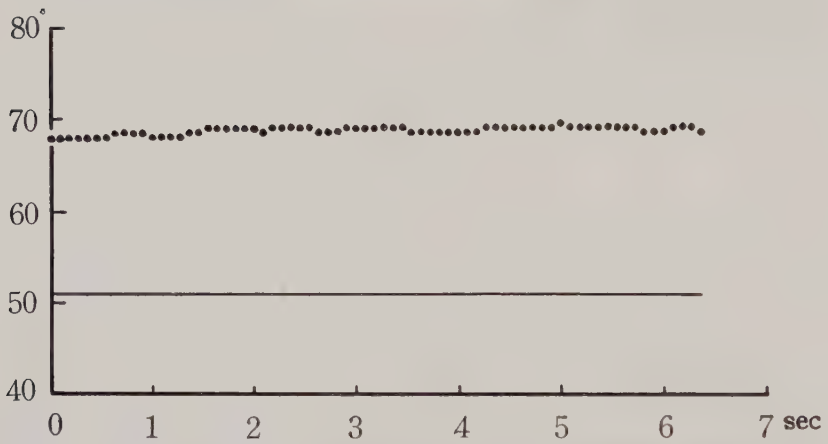

Fig. 18. The movement of the index of the current-measuring device.

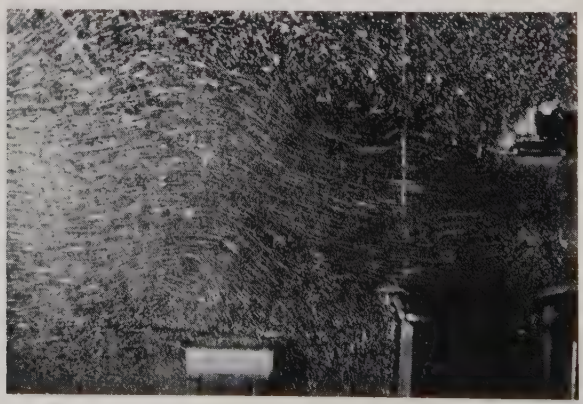

Fig. 19. A photograph showing the appearance of the stream at the mouth of the bay model and its vicinity.

Fig. 19 is a photograph showing the appearance of the stream at the mouth of the bay model and its vicinity when a standing oscillation is produced in the bay model by the current. One sees that Kármán vortices, unsymmetrically arranged, appear on both sides of the jet and that the stream lines meander.

The period of oscillation of the bay water as measured from the records shown in Fig. 16, is $T_{obs}=0.75$ sec on an average. On the other hand, if the free period of oscillation of bay water is calculated by Merian's formula $T=4L/\sqrt{gh}$, then $T_{cal}=\frac{4\times10}{\sqrt{980\times4}}=0.64$ sec, which agree reasonably well with the observed period.*

Next, the depth of water h was varied to 3.5 cm, 3.0 cm, 2.5 cm, 2.0 cm, 1.5 cm and 1.0 cm, and for each of these cases the experiment as mentioned above was repeated. In every case it was ascertained that conspicuous standing oscillations were induced in the bay model by a steady current of appropriate strength, although the oscillation becomes fairly irregular, perhaps due to the effect of friction, as the depth of water becomes as small as 1.5 cm.

In the annexed table (Table 1), the first column gives the values of the depth of water h in cm, the second column the observed values of the period of oscillation of bay water T_{obs} in sec, read off from the records for respective cases, and the third and the fourth columns the calculated values T_{cal} and T'_{cal} of the proper period of oscillation of the bay model, calculated by the formulas $T=4L/\sqrt{gh}$ and $T=4L/\sqrt{\frac{2gL}{\pi}\tanh\frac{\pi h}{2L}}$, respectively.

Table 1

Depth of water, h (cm)	T_{obs} (sec)	T_{cal} (sec)	T'_{cal} (sec)
1.0	1.08	1.28	1.28
1.5	1.02	1.04	1.05
2.0	0.93	0.90	0.92
2.5	0.80	0.81	0.83
3.0	0.76	0.74	0.76
3.5	0.76	0.68	0.72
4.0	0.75	0.64	0.68

* One of the reasons why the calculated value of T is somewhat smaller than the observed one will perhaps be as follows: Namely, in the present case since the ratio of the depth of water h to the wave length λ $(=4L)$ is 1:10, the wave is not strictly a long wave, but an "intermediate wave" whose velocity of propagation is given by $\sqrt{\frac{g\lambda}{2\pi}\tanh\frac{2\pi h}{\lambda}}$ instead of $\sqrt{gh}$. Hence the period of oscillation T is rather given by $4L\Big/\sqrt{\frac{2gL}{\pi}\tanh\frac{\pi h}{2L}}$ than $4L\Big/\sqrt{gh}$. In Fig. 20, the solid line corresponds to the values calculated by Merian's formula $T=4L/\sqrt{gh}$, and the broken line to those calculated by $T=4L\Big/\sqrt{\frac{2gL}{\pi}\tanh\frac{\pi h}{2L}}$. The difference between the two cases is not large.

Fig. 20 represents the above table diagrammatically, from which it can be seen that T_{obs} and T_{cal} (or T'_{cal}) are in fairly good agreement.

Now, as mentioned before (§2), according to the theory of Kármán vortices, there exists a relation

$$N\,l=u$$

among N, l and u, where N denotes the frequency of the swing of a jet, l the

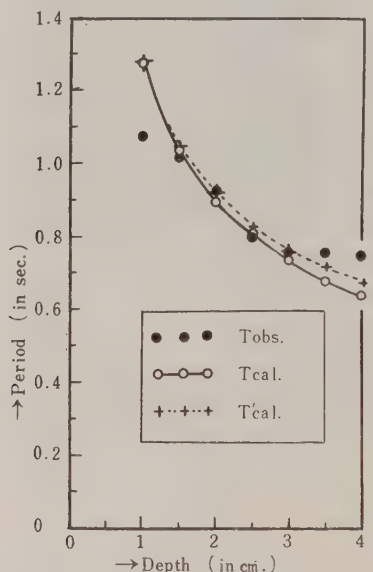

Fig. 20. Comparison between the observed and calculated values of the period T.

distance between any two successive vortices lying on one side of the jet, and u the travelling velocity of the system of vortices. Therefore, if we consider the case where the period of the swing of the jet coincides with the natural period of oscillation of bay water and "resonance" occurs, the following relation should hold good approximately:

$$\frac{l}{u}=T=\frac{4L}{\sqrt{gh}}\,. \qquad (2)$$

To see if the last-mentioned relation actually exists, the following experiment was carried out.

At the time when conspicuous standing oscillations are being induced in the bay model, the positions and changes of the vortices forming on the edges of the jet were photographed at short time intervals with two 35-mm cameras (Leica; Camera A and Camera B), and from each pair of photographs thus taken l and u were obtained. (See Fig. 21 A, B.) In these photographs large oscillations were being induced in the bay model by a steady current whose

velocity was about 18 cm/sec, the depth of water being 3.0 cm. One notices two vortices lying on the right-hand side of the jet, close to the exit of the canal,

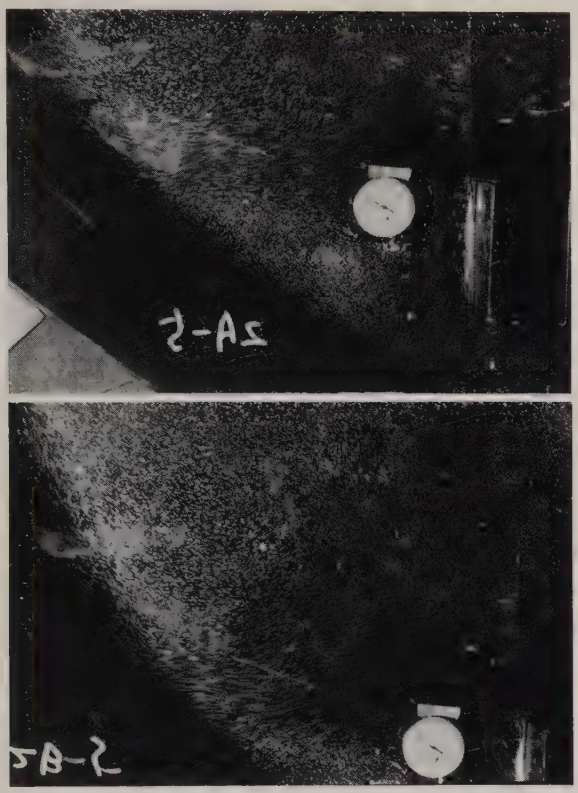

Fig. 21. A pair of photographs showing the movements of vortices accompanying the jet of current, taken with cameras A and B. The photograph B followed that of A by one-half second*

and flowing downstream one after the other. A rather thick white line-segment which is seen near the vortices is the image of a small piece of woolen yarn set afloat on the surface of water in order to measure the velocity of the current and the time interval between the times of taking the two photographs.

Let t be the time interval between photographs A and B, u the mean velocity of the system of vortices downstream during that interval, V the velocity of the general current (undisturbed velocity of the stream), and l the mean mutual distance of the two vortices under consideration. These quantities can be measured as follows:

Figs. 22A and B show schematical representations of the two vortices under consideration in the photographs of Figs. 21A and B, respectively. In each

* At the time of taking these photographs the vane in the bay model was removed temporarily for convenience in the placement of the cameras. The oscillation of bay water is almost indifferent to the existence of this vane.

of these figures, let the quantities for the right-hand vortex (the vortex nearer to the bay model) be appended with suffix 1, and those for the left-hand vortex (the vortex farther from the bay model) with suffix 2. Again, let the quantities corresponding to the figure A be marked with the sign′, and those corresponding to the figure B with the sign″. Then the mean distance between the two vortices under consideration, l, is obtained from

$$l = \frac{l' + l''}{2} \tag{3}$$

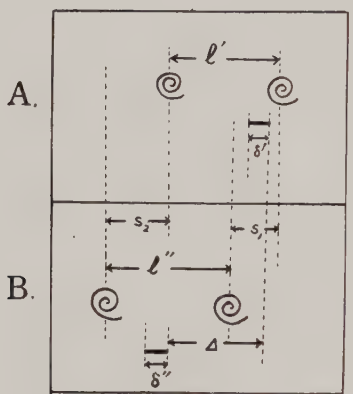

Fig. 22. Schematical representations of the vortices appearing in Fig 21.

Next, let δ' and δ'' be the lengths of the images of the said piece of woolen yarn (or aluminium powder)* appearing in photographs A and B, respectively, and τ' and τ'' the times of exposure of the two photographs, respectively; then the velocity of the jet of current (undisturbed velocity of the stream) V** is obtained from

$$V = \frac{1}{2}\left(\frac{\delta'}{\tau'} + \frac{\delta''}{\tau''}\right). \tag{4}$$

In the present example, τ' and τ'' are almost equal to each other and are both 0.044 sec.*** Hence

$$\tau' = \tau'' = \tau \ (= 0.044 \text{ sec}).$$

Accordingly, if we write $(\delta' + \delta'')/2 = \delta$, we have

$$V = \frac{\delta}{\tau} \tag{5}$$

in place of (4).

---

* In case of aluminium powder, the length of the image appearing in the photograph was regarded as δ, since the granules of aluminium powder are small; but in case of the piece of woolen yarn, allowance was made for its size (or diameter of the piece assumed spherical) and the rest of the length was regarded as δ.

**Of course, the value of V differs for different points, but here we are considering a point on the central line of the jet close to the bay model.

***This value was determined by the method described in (III), (c) (Method 3).

Again, let Δ be the distance through which the piece of woolen yarn drifted during the time interval t (Fig. 22), then

$$V = \frac{\Delta}{t}. \tag{6}$$

Accordingly,

$$t = \frac{\Delta}{V} = \frac{\Delta}{\delta}\tau. \tag{7}$$

Now, let s_1 and s_2 be the distances through which each of the vortices under consideration travels during the time interval t; then their velocities of travel, u_1 and u_2, are:

$$u_1 = s_1/t, \qquad u_2 = s_2/t,$$

respectively, and hence the velocity of travel, u, of the system of vortices under consideration as a whole is given by

$$u = \frac{u_1 + u_2}{2} = \frac{s_1 + s_2}{2t}.$$

Put $\frac{s_1+s_2}{2} = s$, then $u = \frac{s}{t}$, or by (7)

$$u = \frac{s\delta}{\Delta\tau}. \tag{8}$$

Thus the quantities required, l, V, t and u, can be calculated by (3), (5), (7) and (8), respectively, by using the quantities which can be measured directly on the photographs.

Application of the above method to A and B of Fig. 21 gives the results shown in the first row of Table 2.

From several dozens of photographs taken under the same conditions as above (depth of water, $h = 3.0$ cm) six pairs of photographs were selected in which identification of vortices was possible and also in which the necessary quantities could be measured accurately. For these the quantities mentioned above were obtained and are given in rows two to seven of Table 2.

Table 2 shows that the value of l/u averages 0.79 sec, which is in near accord with the observed period 0.76 sec of the standing oscillation of bay water. In other words, the relation

Table 2

No. of photograph pair	l (mm)	s (mm)	δ (mm)	Δ (mm)	u (mm/sec)	V (mm/sec)	l/u (sec)	u/V
1	58	26	8.0	64	73.9	182	0.79	0.40
2	72	36	7.8	72	88.6	177	0.81	0.50
3	70	30	8.0	64	85.2	182	0.82	0.47
4	60	32	8.0	76	76.6	182	0.78	0.42
5	61	59	6.5	101	86.3	148	0.71	0.58
6	60	48	5.6	84	72.7	127	0.83	0.57
7	60	52	6.4	100	75.6	145	0.79	0.52

$$l/u=T$$

holds good approximately. Since this method is somewhat rough as mentioned above, it is inevitable that the values obtained may contain errors; and it follows that the same quantity does not always give the same value for individual cases. However, so far as the quantity l/u is concerned, the individual results agree fairly well with each other and at the same time they agree with the value of T. And this fact seems to verify that the said standing oscillation of water in the bay model is caused by the horizontal swing of the jet of current due to the formation of Kármán vortices.

In addition, according to Table 2 the velocity of travel of the system of vortices, u, is about 7–9 cm/sec, and the undisturbed velocity of the current, V, is about 13–18 cm/sec, the former being equal to about 40–60% of the latter.

4. Comparison of the Magnitudes of Quantities between the Model and the Actual Case

From the foregoing discussions and the above experiment it is clear that the standing oscillation of water (secondary undulations of tides) can be induced in bays by tidal or oceanic currents. But in order that such oscillations actually occur it is necessary that the velocity of actual currents be fairly large in comparison with the velocity of the current flowing across the mouthline of the bay due to the standing oscillation.

Let v be the mean velocity of the current flowing through the mouth of the bay due to the standing oscillation (secondary undulations of tides), S the area of the bay, b the breadth of its mouth, h the mean depth, H the range of rise and fall of water level at the end of the bay farthest from its mouth ("beach"), and T the period of the secondary undulation; then the quantity of water flowing through the mouth of the bay during a quarter period due to the secondary undulation is $bhv\left(\frac{T}{4}\right)$. Now, since the secondary undulation which usually occurs in a bay is a standing oscillation with its node and loop of vertical motion at the mouth of the bay and its beach, the increase or decrease of water quantity in the bay due to the rise or fall of water level can be expressed by $\left(\frac{H}{4}\right)S$ approximately. Therefore $bhv\left(\frac{T}{4}\right)=\left(\frac{H}{4}\right)S$, and

$$v=\frac{SH}{bhT} \quad . \tag{9}$$

Applying the expression (9) to the case of Shioyasumi Bay,

$S=25000\text{m}^2=25\times10^7\text{cm}^2$, $b=200\text{m}=2\times10^4\text{cm}$, $h=3$ m $=3\times10^2\text{cm}$, $H=18$ cm, $T=2.5$ min $=150$ sec. $\therefore$ $v=5.0$ cm/sec.

On the other hand, if $V=10$ kt $\fallingdotseq 500$ cm/sec (the maximum velocity of tidal current in the Strait of Naruto is 10 knots), then

$$\frac{v}{V}\fallingdotseq\frac{5.0}{500}=\frac{1}{100} \quad .$$

Again, if we take $V=5$ kt, then

$$\frac{v}{V} \fallingdotseq \frac{1}{50}.$$

Next, we shall examine the magnitude of v/V for the case of the model experiment. For example, in the case of the experiment mentioned in §3 (Fig. 16a), the value of V was about 13 cm/sec, while that of v was about 1.7 cm/sec ($S = 50\text{cm}^2$, $b = 5$ cm, $h = 4$ cm, $H = 0.5$ cm* and $T = 0.75$ sec). Accordingly, $\frac{v}{V} = \frac{1.7}{13} \approx \frac{1}{8}$. Thus, it can be seen that the value of V is far larger than that of v both in the actual case and in the model.

Next, we shall compare between the model and nature the relative magnitudes of the quantities L, h, T (length, depth and period of the secondary undulation of the bay). Let L', h', T' be the corresponding quantities for the model, and further put

$$L=\alpha.L', \qquad h=\beta.h', \qquad T=\gamma.T': \tag{10}$$

then, since

$$T=\frac{4L}{\sqrt{gh}}, \qquad T'=\frac{4L'}{\sqrt{gh'}} \tag{11}$$

we should have

$$\gamma=\frac{\alpha}{\sqrt{\beta}}. \tag{12}$$

In the present case

$$\alpha=\frac{L}{L'}\fallingdotseq\frac{180\times10^2}{10}=1800,$$

$$\beta=\frac{h}{h'}\fallingdotseq\frac{3\times10^2}{4}=75,$$

$$\gamma=\frac{T}{T'}\fallingdotseq\frac{2.5\times60}{0.75}=200.$$

Therefore, Equ. (12) holds good approximately.

5. Concluding Remarks

A discussion was made on the mechanism of excitation of the standing oscillation of bay water (secondary undulations of tides) by tidal or oceanic currents, and a model experiment was carried out in order to verify the theory. It was shown that when the velocity of current exceeds a certain limit, periodic and unsymmetric Kármán vortices are formed on both sides of the jet of current and hence the jet tends to swing horizontally, causing a standing oscillation of bay water, and that when the period of swing of the jet coincides with the natural period of oscillation of bay water, vigorous oscillations of water are induced in the bay as the results of resonance.

Acknowledgements:— The authors desire to acknowledge the assistance rendered in this investigation through a grant from the Japanese National Commission for Unesco under contract with the Japan Society for the Promotion of Science.

* The observed range of rise and fall of water level at the recess of the bay model.

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October 1959

WATER TEMPERATURE FLUCTUATIONS OFF MUROTO, SHIKOKU

By
Shigeo Hikosaka and Ryoji Higano

Abstract

Results of water temperature observations off Muroto, Shikoku, are analysed and auto-correlation coefficients are calculated. These results give rise to the 4/3 power formula for small process-time t as

$$1-R(t)\propto t^{4/3}$$

which Dr. Inoue pointed out in the atmospheric pressure or temperature fluctuations.

Then, the passage-time and the scale of the largest or predominant turbulon are estimated.

1. Introduction.

Recently, the similarity theory of turbulence has been much advanced in meteorology. Many observations of wind, temperature and pressure fluctuations in the atmosphere have been made and these results show that the similarity theory is applicable to the atmospheric element-fluctuations.

In the ocean, however, only a few observations have been made to test this similarity theory of turbulence (for example, Nannichi, Bowden, Nitani). Nannichi (1957) showed the water temperature fluctuations were expressed by the so called 4/3 power formula from the water temperature observations off Tsurumi, Tokyo Bay.

On the other hand, Nitani (1958) showed the ⅔ power formula was held based upon the results of water temperature observations in Maizuru Bay. But to the present authors the above discrepancy is caused by the process-time intervals with which the records were analysed, as has been shown by Dr. Inoue (1955).

The water temperature observations described in the present paper were made off Muroto, Shikoku and auto-correlation coefficients were calculated. The results represent a fair agreement with the advanced similarity theory of turbulence.

2. Water Temperature Observations and Records.

The observations have been made off Muroto, Shikoku and the measuring instruments were 3 sets of thermister.

About every minute at each station, temperature fluctuations were recorded on the paper of a mili-volt meter. Records 1, 2 and 3 were obtained at the

Fig. 1. Chart of Muroto Misaki Kō. ○: positions of stations.

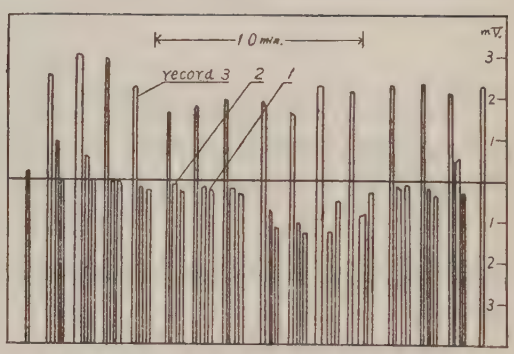

Fig. 2. Part of record. Records 1, 2 and 3 were obtained at the stations 1, 2 and 3 respectively.

stations 1, 2 and 3 respectively with about two and a half days duration from August 29, to Sept., 1, 1957. Records 1, 2 were at heights of 1 m. above the bottom and record 3 of 4.5 m. and stations 1 and 3 were about 300 m. distant from the coast and station 2 about 150 m..

3. Analysis of records and discussions.

Tow records of stations 2 and 3 were read off every minute and were analysed. Each averaging-time of analysis was of 400 min. The results of auto-correlation coefficients calculations are represented in Table 1.

Table 1. Auto-correlation coefficients

record	z	auto-correlation coefficients (process-time t in min.)															
	(m)	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	25
2	1.0	.96	.90	.84	.79	.75	.70	.67	.63	.59	.56	.49	.44	.43	.42	.40	.33
3	4.5	.95	.85	.77	.71	.67	.64	.61	.58	.55	.51	.46	.42	.38	.34	.31	.23
mean		.95	.87	.80	.75	.71	67.	64.	.61	.57	.54	.48	.43	.40	.38	.36	.28

30	35	40	45	50	55	60	70	80	90	100	110	120	130	140	150
.32	.20	.16	.15	.15	.19	.18	.02	.05	—.01	—.16	—.13	—.29	—.37	—.38	—.44
.15	.07	—.01	—.05	—.11	—.11	—.12	—.22	—.17	—.03	—.07	—.01	—.08	—.20	—2.1	—.23
.24	.13	.07	.05	.02	.04	.03	—.10	—.06	—.02	—.11	—.07	—.18	—.29	—.29	—.33

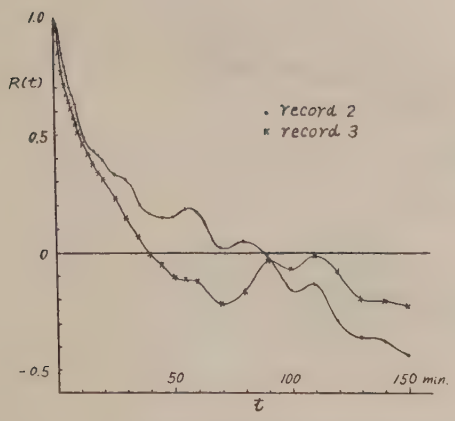

Fig. 3a. Eulerian correlation coefficients in records 2 and 3.

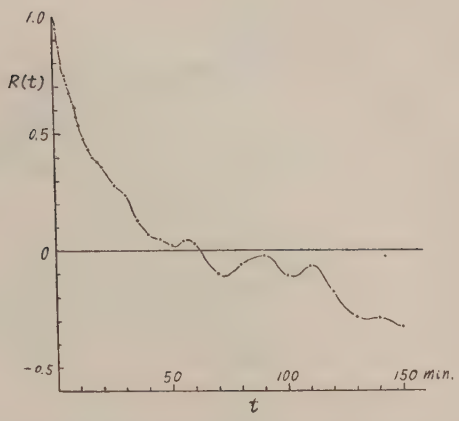

Fig. 3b. Mean Eulerian correlation coefficient in records 2 and 3.

From the above table, the auto-correlation coefficients of record 2 were larger than those of record 3 in less the process-time 90 minuts. Fig. 3a., b. show the auto-correlation function curves. From these figures, we can see there is about 30 min. period fluctuation but we could not detect by what this fluctuation was caused such as internal waves or seiches.

Fig. 4a.,b. show the Logarithmic representations of auto-correlation coefficients function. As can be seen from these figs. 4a and b, the results hold the 4/3 power formula for the small process-time t, i.e. $1-R(t) \propto t^{4/3}$ which Dr. Inoue pointed out in his paper.

According to Inoue (1955), Eulerian or passage-time correlation function of medium scales can be expressed

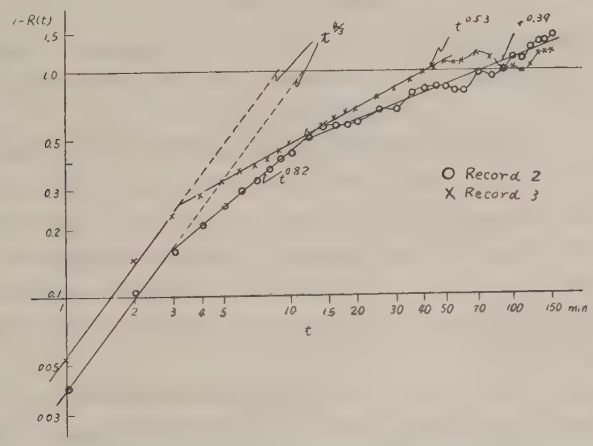

Fig. 4a. Logarithmic representation of Eulerian correlation coefficients in records 2 and 3.

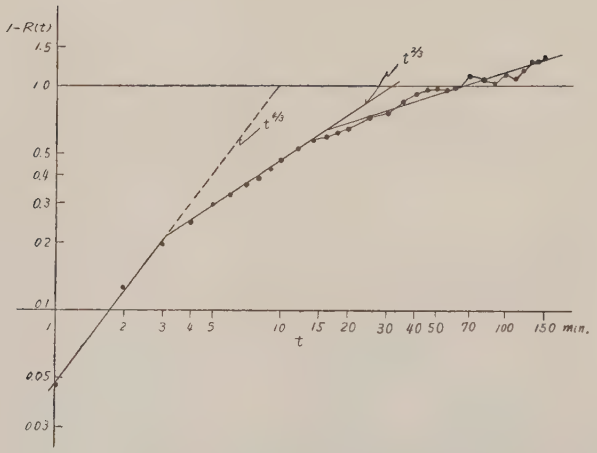

Fig. 4b. Logarithmic representation of mean Eulerian correlation coefficient in records 2 and 3.

$$R\left(\frac{t}{T_o}\right)=\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{1}{3}\right)\sum_{m=0}^{\infty}\left(\frac{t}{2T_o}\right)^{2m}\times\left\{\frac{m+1}{\Gamma\left(m+\frac{1}{2}\right)\Gamma\left(m+\frac{1}{3}\right)}\right.$$

$$\left.\frac{m+\frac{5}{3}}{\Gamma\left(m+1\right)\Gamma\left(m+\frac{7}{6}\right)}\left(\frac{t}{2T_o}\right)^{4/3}\right\}$$

and in the region of small (t/T_0) the above $R(t/T_0)$ is shown to be

$$R\left(\frac{t}{T_o}\right)=1-\frac{5}{2}\Gamma\left(\frac{2}{3}\right)\left(\frac{t}{T_o}\right)^{4/3}+\cdots\cdots$$

$$=1-3.386\,(t/T_o)^{4/3}+\cdots\cdots$$

where T_0 is regarded as the passage time of predominant turbulon.

If we put $T_p=0.4006T_0$ or $T_0=2.496\,T_p$, the 4/3 power law is represented by

$$1-R(t/T_p)=(t/T_p)^{4/3}$$

Consequently, our previous auto-correlation coefficients are represented by the function (t/T_0) and Fig. 5 shows the above relations. Then we can easily find that there is a representative dotted curve through each point and a solid heavy line is the theoretical curve from the above formula obtained by Inoue. While, Y. Ogura and Miyakoda (1954) obtained the spatial correlation of pressure fluctuations from the different hypothesis from Inoue's and the results are shown with a thin line in Fig. 5.

Compared our results with Inoue's and Ogura-Miyakoda's curves, our results, it is seen, are slant more than Inoue's and Ogura-Miyakoda's ones.

From fig. 4, we find the passage-time T_p is about 10 min. So, if we assume that the mean current velocity is 50 cm. ($=1$ *kt.*), the scale of the largest or

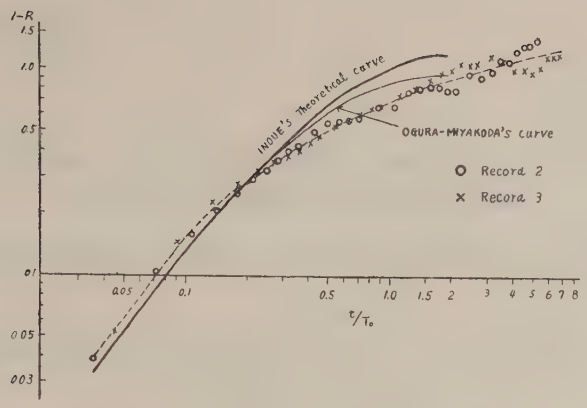

Fig. 5. Comparison of our results with Inoue's theoretical correlation curve and with Ogura-Miyakoda's.

the predominant turbulon is about 300 m. This value gives a good agreement with the distance of the station from the coast.

4. Acknowledgement.

The authors wish to express their thanks to Dr. E. Inoue of the National Institute of Agricultural Sciences for valuable advices of this investigation and to Messrs. R. Watanabe, S. Yoshida and W. Inada of Hydrographic Office for preparing observations. They are also indebted to Miss. Wakako Suzuki for assistance in the calculations.

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BASIC STUDIES FOR THE NEW METHOD OF SEPARATION OF IODINE FROM NATURAL-WATERS

Adsorption of Iodine to Polyvinyl Glycerin Acetal

By
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and Takashi Teramoto
(Faculty of Science, Kyoto University and Faculty of Science,
Okayama University)

I. Introduction

It is known that polyvinyl alcohol (P.V.A.)[1] and polyvinyl acetal form a coloured compound by the adsorption of iodine. Especially, polyvinyl formal[2] has an excellent adsorption to iodine. From the fact that polyvinyl glycerin acetal (P.V.G.A.)[3] forms a brown-black compound by the adsorption of iodine, the relation of P.V.G.A. and iodine was studied.

II. Experiment

1. Acetal Value and Adsorption

The effects of the adsorption of iodine upon polyvinyl glycerin acetals at their various acetal values were studied. (Table I, Fig. 1)

Table I. Acetal Value and Adsorption

Ex. No.	Acetal value	Equilibrium Concentration	Adsorption	
		N	mg	%
1	3.2	0.0305	157.2	24.5
2	3.7	0.0306	155.4	24.3
3	4.6	0.0302	158.8	24.8
4	5.3	0.0302	158.8	24.8
5	7.0	0.0301	160.8	25.3
6	8.7	0.0300	165.1	25.7
7	9.5	0.0300	165.1	25.7
8	12.5	0.0298	167.5	26.2
9	14.4	0.0295	173.5	27.0
10	17.5	0.0294	174.5	27.2

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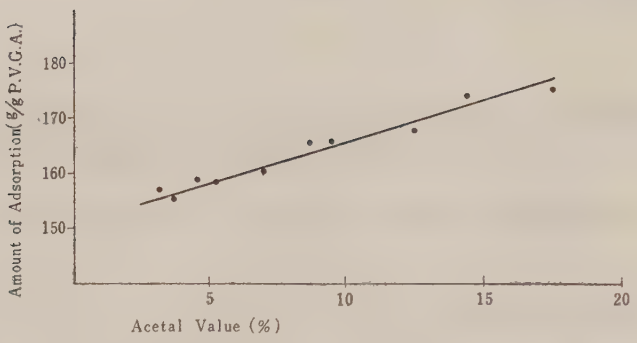
2) Masamori Yamada: Chem. of High Polymers, Japan, *6*, 356 (1949).
3) Masayoshi Ishibashi, Koichi Emi, Tamotsu Matsumoto, Kiichiro Sando, Toru Komiyama: Bulletin of the Soc. of Salt Science, Japan, *12*, 244 (1958).

Fig. 1



Since a linear relation exists between the amount of adsorption of iodine and the acetal value of P.V.G.A., it was found that the former increased with increase of the latter. (Fig. 1)

2. Adsorption Velocity

The relation of the concentration of iodine solution and the adsorption velocity of iodine was studied. The addition ratio mentioned in Table II

$$= \frac{\text{P.V.G.A. taken (wt)}}{\text{Iodine added (wt)}}$$

The P.V.G.A. used in later experiment has acetal value 12.5.

Table II. Adsorption Velocity

1. Initial Concentration 0.0920 N Addition Ratio 0.43

Time (min)	5	15	40	70	100	160	280	480
Adsorption (g)	0.0851	0.1463	0.2032	0.2286	0.2540	0.2834	0.3150	0.3312

2. Initial Concentration 0.0457 N Addition Ratio 0.87

Time (min)	5	15	40	70	100	160	280	1200
Adsorption (g)	0.0514	0.0852	0.1346	0.1626	0.1753	0.2032	0.2361	0.2565

3. Initial Concentration 0.0144 N Addition Ratio 2.10

Time (min)	5	15	40	90	180	280	1440	1800
Adsorption (g)	0.0251	0.0494	0.0755	0.0803	0.1097	0.1152	0.1322	0.1335

4. Initial Concentration 0.0086 N Addition Ratio 4.3

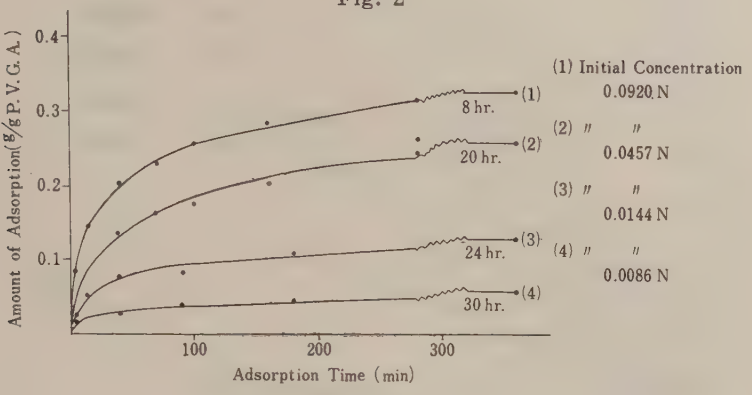
Time (min)	5	15	40	90	180	280	1440	1800
Adsorption (g)	0.0166	0.0203	0.0297	0.0395	0.0457	0.0482	0.0609	0.0620

The adsorption velocity of iodine increases with increase of the concentration of iodine solution, and it falls suddenly with decrease of the concentration.

Consequently, the adsorption velocity reaches quickly to equilibrium at the high concentration and slowly at the low concentration.

The plot of the amount of iodine adsorbed in one gram of P.V.G.A. against the logarithm of adsorption time is shown in Fig. 2.

Fig. 2



At the begining of the adsorption, it shows a straight line having different slope in every concentration. Accordingly, there is exponential function between the time and the amount of adsorption. The slope is steep with increase of the concentration, and gentle with decrease of the concentration. From this slope, the extent of adsorption velocity may be found.

3. Addition Ratio and Adsorption

In order to test for the relation of the concentration of iodine solution and the amount of iodine absorbed, the effect of addition ratio upon adsorption at the same concentration was studied. (Fig. 3, Fig. 4)

Fig. 3

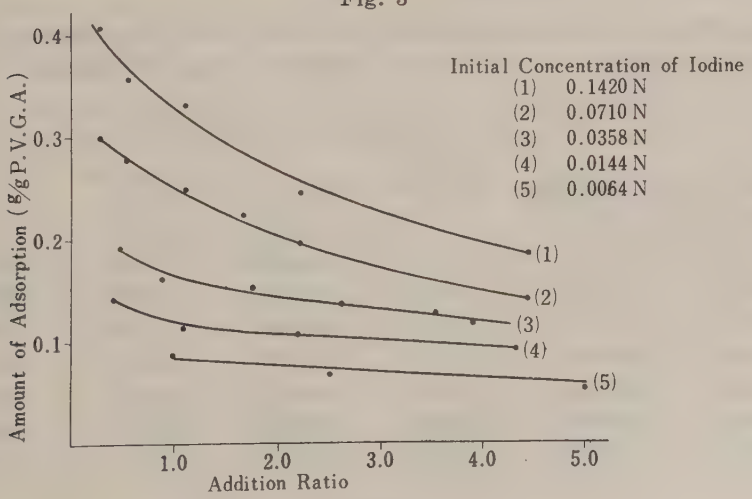
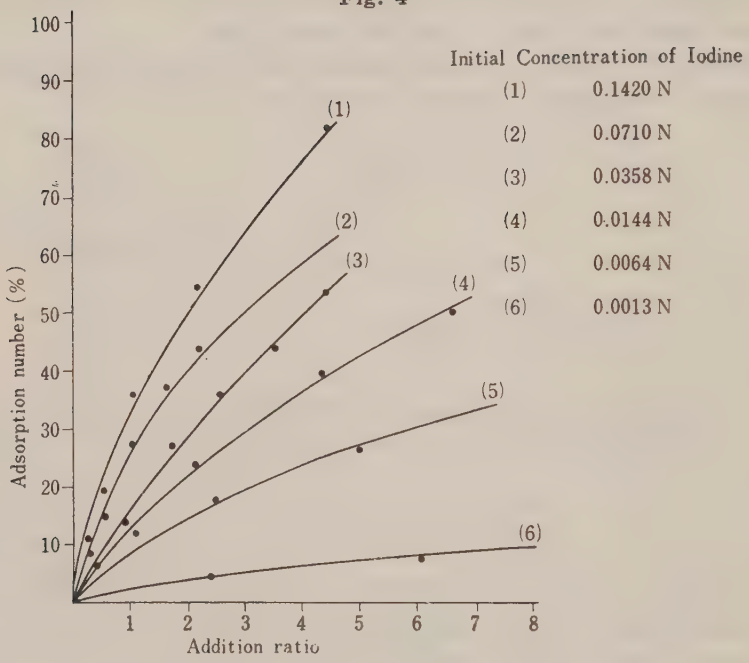


Fig. 4



As shown in Fig. 3, the amount of iodine adsorbed increases with decrease of the addition ratio at the same concentration of iodine solution and decreases suddely with increase of the addition ratio at the high concentration, but it does not decrease so remarkably at the low concentration.

Adsorption number expressed in per cent increases with increase of the initial concentration at the same addition ratio and with increase of the addition ratio. (Fig. 4)

4. Concentration and Adsorption

The relation of the concentration of iodine and the amount of iodine adsorbed was tested at nearly the same addition ratio. (Table III)

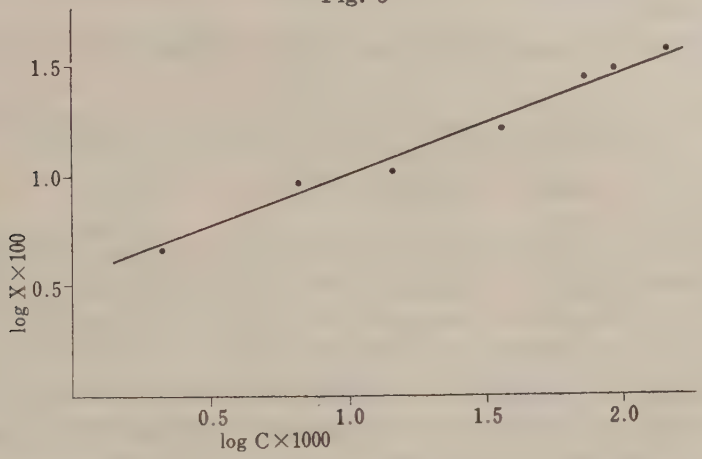
Table III. Concentration and Adsorption

Initial Concentration	Equilibrium Concentration	Addition Ratio	Adsorption		
			Found	%	Calcd
N	N		g		g
0.1420	0.1140	0.554	0.3556	11.2	0.3842
0.0930	0.0730	0.670	0.3175	21.5	0.3054
0.0710	0.0600	0.554	0.2794	8.3	0.2635
0.0358	0.0322	0.440	0.1681	8.4	0.1813
0.0144	0.0135	0.440	0.1032	6.3	0.1102
0.0064	0.0055	1.000	0.0876	14.1	0.0708
0.0021	0.0020	1.500	0.0318	5.1	0.0385

The amount of iodine adsorbed increases with increase of the concentration of iodine solution.

A plot of logarithm of the concentration of this solution (C) against the amount of iodine adsorbed (X) is shown in Fig. 5.

Fig. 5



In the range of this concentration, the result is a straight line, which is applicable to the equation of "Freundlich adsorption isotherm", but this equation holds only when the addition ratio is almost the same.

Calculating the constants from the experimental data by arithmetical mean method, it follows that

$$X = 1.117 \cdot C^{0.546}$$

Calculated value mentioned in Table III denotes the amount of iodine adsorbed, which is calculated by means of this equation, and this value is almost agreed with experimental one.

5. Potassium Iodide and Adsorption

Potassium iodide is necessary for the preparation of the stable iodine solution, but whether the amount of iodine adsorbed will be accelerated by potassium iodide or not, was studied with the solution prepared by changing the amount of potassium iodide against a definite amount of iodine. (Table IV) From this

Table IV. Potassium Iodide and Adsorption

KI : I_2	Initial Concentration	Equilibrium Concentration	Addition Ratio	Adsorption	
wt ratio	N	N		g	%
1	0.0095	0.0075	5.00	0.0420	21.1
2	0.0096	0.0073	4.92	0.0487	24.0
4	0.0096	0.0074	4.92	0.0466	22.9
0	0.0007	0.0006	47.51	0.0032	14.2
1	0.0007	0.0004	47.51	0.0095	42.9

experiment, it is evident that the adsorption of iodine is accelerated by potassium iodide.

6. Temperature and Adsorption

The relation of the temperature and the amount of iodine adsorbed was studied. (Table V)

Table V. Temperature and Adsorption

Temperature	Initial Concentration	Equilibrium Concentration	Addition Ratio	Adsorption	
°C	N	N		g	%
13	0.0276	0.0238	1.14	0.1207	13.8
20	0.0276	0.0233	1.14	0.1382	15.6
30	0.0276	0.0230	1.14	0.1462	16.7
40	0.0276	0.0234	1.14	0.1333	15.2
50	0.0276	0.0232	1.14	0.1397	15.9

In the range of temperature mentioned in Table V, the slight differences were found among the amounts of iodine adsorbed, and the effect of temperature on the amount of iodine adsorbed were scarcely observed.

7. Hydrogen Ion Concentration and Adsorption

Changing the hydrogen ion concentration of iodine solution, the effect of pH on the adsorption of iodine was studied. Consequently, it was found that pH of the iodine solution had not any effect on the amount of iodine adsorbed. (Table VI)

Table VI. Hydrogen Ion Concentration and Adsorption

pH	Initial Concentration	Equilibrium Concentration	Addition Ratio	Adsorption	
	N	N		g	%
7	0.0331	0.0216	2.44	0.1461	34.7
5	0.0331	0.0216	2.44	0.1461	34.7
1	0.0331	0.0218	2.44	0.1435	34.4

III. Conclusions

(1) The amount of iodine adsorbed in P.V.G.A. increases with increase of the acetal value. Consequently, when P.V.G.A. having higher acetal value is synthesized, the amount of iodine adsorbed in P.V.G.A. will, perhaps, greatly increase.

(2) The adsorption velocity increases with increase of the concentration of iodine solution and decreases suddenly with decrease of the concentration.

(3) The amount of iodine adsorbed in P.V.G.A. in the same addition ratio varies according to the "Freundlich adsorption isotherm".

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CHEMICAL STUDIES ON THE SEAWEEDS, III

The Content of Ash, Sodium and Potassium in Seaweeds

By
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(Faculty of Science, Kyoto University)

Considerable information is available on the occurrence of various elements in seaweeds, but it is far from complete for any biological group. In 1952, Black and Mitchell[1] reviewed the work which had been done in this field.

Ishibashi and Sahara[2] (1940) carried out spectrographic analysis of four seaweeds and found the following elements: Hg, Bi, Sn, Cr, Ba, Sr, Li, Rb, Re, Ti and V, and figures are given for Na, K, Ca, Mg, Fe, Al, Mn, P, Si, S, and Cl as major inorganic constituents. The same workers[3] (1940) devised a method for the determination of Cl, Br and I in seaweeds. The present paper is a continuation of the studies mentioned above.

The content of inorganic constituents in seaweeds will probably depend on the species and on the stage of development, and some variation will occur in different habitats where the seaweeds are growing, but no detailed investigation of these subjects appears to have been carried out.

The authors collected various species of seaweeds in one habitat through all seasons, and they determined the content of Ash, Sodium and Potassium in the samples. The results are as follows.

Material and Methods

Collection of seaweeds.

Seaweeds used for the present experiments were collected at the coast of the "Tomo" island of Wakayama prefecture in Japan. The nomenclature of the species was mainly owed to Mr. Sôishirô Sakaguchi.

Treatment of seaweeds.

Fresh seaweeds were washed with sea-water and dried in the shade, then, in order to remove sea-water, they were washed repeatedly with distilled water quickly, untill the washing showed no more $AgNO_3$ reaction. The wet materials were dried at 40° to 50°, and stored in the closed box.

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Determination of Ash.

Analyzed samples were carefully selected to avoid any contamination. The samples were dried at 105° for about two hours, weighed, and ashed gradually at 400° to 500° in an electric-furnace. Table II shows the effect of the time of ashing.

Determination of Sodium and Potassium.

One gram of the ashes was extracted* with boiling water, acidified slightly with acetic acid, and diluted to 200 ml, 25 ml or 50 ml of this solution was pippeted for the analysis. Sodium was determined by the uranyl-magnesium acetate method, and Potassium by the sodium-cobaltinitrite method. Table III shows the reproducibility of the quantitative values determined by the above method.

Table I. The Effect of Washing on the Determination of Ash in Seaweeds

Total Ash (% of dry matter)

No. of Sample	Species	Unwashed				Washed			
					Average				Average
13	Padina arborescens	37.5	37.0	36.9	37.1	18.8	18.8	18.7	18.8
15	Padina arborescens	33.2	33.9	33.7	33.6	15.6	16.0	15.8	15.8

Table II. The Effect of the Time of Ashing

Total Ash (% of dry matter)

Ashing				Average
8 hours	15.95	15.95	15.75	15.88
14 hours	15.95	15.93	15.77	15.88

Ulva conglobate was used. Ashing was carried out at 450°.

Table III. Determination of Sodium and Potassium in Several Seaweeds

No. of Sample	Species	Sodium (% in Ashes)				Potassium (% in Ashes)			
					Average				Average
28	Sargassum Ringgoldianum	4.50	4.47	4.49	4.49	10.85	11.09	10.98	10.97
34	Sargassum Piluliferum	4.25	4.19	4.11	4.18	3.79	4.00	3.91	3.90
38	Ishige Okamurai	12.46	12.22	12.35	12.34	6.14	6.23	6.03	6.13
41	Sargassum Thunbergii	4.44	4.46	4.40	4.43	12.02	12.02	12.03	12,02

* The washing of the residue was always checked for the absence of Cl^- to ascertain whether the extraction was complete or not. In such a case, it was spectrographically shown that the residue contained neither sodium nor potassium at a measurable extent.

Table IV. The Content of Ash, Sodium and Potassium in Brown Sea-Weeds (1)

Family	Species	No.	Collected Date	Total Ash (% of dry matter)	Average	Na (% in Ashes)	Average	K (% in Ashes)	Average	K/Na (atomic ratio)	Average
Encoeliaceae	Myelophycus caespitosus	1	26 Jan. '56	14.2	14.2						
	Scytosiphon lomentarius	2	29 Feb. '56	29.3	29.3	3.39	3.39	2.98	2.98	0.52	0.52
Desmarestiaceae	Desmarestia viridis	3	16 May '56	3.9	3.9	1.11	1.11	1.86	1.86	0.99	0.99
Chordariaceae	Eudesme crassa	4	16 Oct. '55	11.0	11.0	2.12	2.12	1.31	1.31	0.37	0.37
	Chordaria sp.	5	16 Oct. '55	11.4	11.4	4.74	4.74	9.85	9.85	1.22	1.22
Laminariaceae	Eisenia bicyclis	6	26 Jan. '56	16.1		10.28		14.33		0.82	
		7	16 May '56	16.1		10.24		16.35		0.91	
		8	26 May '57	13.8	14.6	8.9	9.97	16.34	15.10	1.02	0.88
		9	28 Aug. '56	14.2		10.37		14.83		0.84	
		10	16 Oct. '55	13.0		10.08		13.64		0.79	
Dictyotaceae	Padina arborescens	11	26 Jan. '56	13.0							
		12	29 Feb. '56	12.5							
		13	16 May '56	18.8	14.7	8.55	8.55	18.98	18.98	1.31	1.31
		14	8 Aug. '55	14.5							
		15	28 Aug. '56	15.8							
		16	16 Oct. '55	13.3							
"	Neurocarpus prolifera	17	28 Aug. '56	10.5	10.5	4.43	4.43	6.70	6.70	0.89	0.89
Sargassaceae	Hizikia fusiforme	18	Jan. '55	15.8							
		19	26 Jan. '56	17.8							
		20	Feb. '54	15.5							
		21	Feb. '55	16.4	18.1						
		22	17 Feb. '53	21.0							
		23	29 Feb. '56	19.6							
		24	15 Mar. '53	19.5							
		25	16 May '56	19.2		8.82	8.82	17.89	17.89	1.19	1.19

Table V. The Content of Ash, Sodium and Potassium in Brown Sea-Weeds (2)

Family	Species	No.	Collected Date	Total Ash (% of dry matter)	Average	Na (% in Ashes)	Average	K (% in Ashes)	Average	K/Na (atomic ratio)	Average
Sargassaceae	Sargassum enerve	26	16 Oct. '55	12.5	12.5	5.70	5.70	10.75	10.75	1.11	1.11
	Sargassum giganteifolium	27	26 Jan. '56	11.9	11.9	4.00	4.00	7.13	7.13	1.05	1.05
„	Sargassum Ringgoldianum	28	26 Jan. '56	15.3		4.49		10.97		1.44	
		29	26 Jan. '56	15.5							
		30	16 May '56	15.3	14.7	4.54	4.87	12.75	11.83	1.65	1.44
		31	8 Aug. '55	13.8							
		32	28 Aug. '56	13.6		5.58		11.78		1.24	
„	Sargassum serratifolium	33	8 Aug. '55	16.4	16.4						
„	Sargassum piluliferum	34	8 Aug. '55	9.6	10.9	4.18	4.18	3.90	3.90	0.55	0.55
		35	8 Aug. '55	12.1							
„	Sargassum Horneri	36	26 Jan. '56	10.2	10.2	3.53	3.53	6.29	6.29	1.05	1.05
	Sargassum tortile	37	16 Oct. '55	11.2	11.2	2.41	2.41	4.86	4.86	1.19	1.19
	Ishige Okamurai	38	29 Feb. '56	12.4	12.4	12.34	12.34	6.13	6.13	0.29	0.29
	Ishige foliacea	39	29 Feb. '56	11.5	11.5						
	Sargassum micracanthum	40	28 Aug. '56	13.7	13.7	4.92	4.92	9.10	9.10	1.09	1.09
„	Sargassum Thunbergii	41	26 Jan. '56	16.1		4.43		12.02		1.59	
		42	29 Feb. '56	17.7		4.63		13.26		1.68	
		43	Mar. '54	19.5		3.68		7.10		1.14	
		44	16 May '56	16.4		6.68		11.78		1.04	
		45	16 May '56	20.5	18.9	5.76	4.77	15.88	11.37	1.62	1.41
		46	8 Aug. '55	17.8							
		47	13 Aug. '54	20.7		3.46		8.20		1.39	
		48	28 Aug. '56	22.3							
		49	16 Oct. '55	19.4							
		50	18 Oct. '52	18.9							

Table VI. The Content of Ash, Sodium and Potassium in Green Sea-Weeds

Family	Species	No.	Collected Date	Total Ash (% of dry matter)		Na (% in Ashes)		K (% in Ashes)		K/Na (atomic ratio)	
					Average		Average		Average		Average
Ulvaceae	Monostroma nitidum	51	26 Jan. '56	23.8	23.8	7.54	7.54	3.21	3.21	0.25	0.25
	Ulva conglobata	52	28 Aug. '56	15.9	15.9	0.65	0.65	1.05	1.05	0.95	0.95
	Ulva sp.	53	16 Oct. '55	16.8	16.8	2.15	2.15	2.79	2.79	0.77	0.77
	Ulva sp.	54	26 Jan. '56	19.0	19.0	1.91	1.91	2.89	2.89	0.89	0.89
	Ulva sp.	55	16 Oct. '55	12.6	12.6						
Cladophoraceae	Cladophora Wrightiana	56	16 Oct. '55	18.0	18.0						
„	Chaetomorpha crassa	57	26 Jan. '56	10.2	11.2						
		58	16 May '56	12.1		5.35	5.35	10.90	10.90	1.20	1.20
Codiaceae	Codium fragile	59	26 Oct. '55	15.0	15.0						
	Codium pugniformis	60	16 May '56	36.0	36.0	18.50	18.50	7.18	7.18	0.23	0.23

Table VII. The Content of Ash, Sodium and Potassium in Red Sea-Weeds

Family	Species	No.	Collected Date	Total Ash (% of dry matter)		Na (% in Ashes)		K (% in Ashes)		K/Na (atomic ratio)	
					Average		Average		Average		Average
Gelidiaceae	Gelidium sp.	61	26 Jan. '56	2.7	3.0						
		62	Aug. '55	3.2		0.56	0.56	0.85	0.85	0.89	0.89
〃	Gelidium sp.	63	16 Oct. '55	6.6	6.6						
〃	Acanthopeltis japonica	64	26 Jan. '56	13.9	12.2		1.50		0.92		0.37
		65	16 May '56	10.3		1.61		1.06		0.39	
		66	28 Aug. '56	13.7		1.38		0.78		0.34	
		67	16 Oct. '55	10.8							
Rhodophyllidaceae	Meristotheca papulosa	68	28 Aug. '56	16.4	16.4						
Sphaerococcaceae	Sarcodia ceylanica	69	29 Feb. '56	10.0	10.0						
	Hypnea Saidana	70	26 Jan. '56	11.0	11.0						
	Hypnea sp.	71	26 Jan. '56	16.4	16.4						
Rhodymeniaceae	Plocamium Telfairiae	72	26 Jan. '56	19.9	19.9						
Gloiosiphoniaceae	Gloiosiphonia capillaris	73	16 May '56	13.1	13.1						
Grateloupiaceae	Grateloupia filicina	74	28 Aug. '56	30.3	30.3						
	Carpopeltis flabellate	75	Mar. '55	9.9	9.9	10.85	10.85	6.60	6.60	0.36	0.36
	Carpopeltis rigida	76	16 May '56	3.6	3.6	3.17	3.17	2.79	2.79	0.52	0.52
Rhizophyllidaceae	Chondrococcus japonicus	77	16 Oct. '55	12.7	12.7						
Potamogetonaceae	Zostera marina	78	16 Oct. '55	16.8	16.8						

Results

The contents of Ash in 43 species, and Sodium and Potassium in 27 species were determined, and the atomic ratio of K to Na was also calculated. These experimental results are summarized in Table IV, V, VI and VII.

Summary

A number of Japanese seaweeds have been analysed, and the content of Ash, Sodium and Potassium was determined. The results show that there is a seasonal variation and considerable variation in the content of these elements in defferent species taken from the same habitat.

It is of interest that the atomic ratio of Potassium to Sodium is varied from 0.23 to 1.65 throughout all over the species examined.

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THE HYDROGRAPHIC CONDITION AND VARIATION OF CALCIUM IN SUSAKI BAY

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I. Preface

The authors have been prosecuting oceano-chemical researches on the productivity of inlets in this country. This is a report on their researches about Susaki Bay, where they have made several measurements and have gained a general knowledge of the hydrographic condition from the distribution of chlorinity and water temperature; logarithms of the ratios of calcium concentration to chlorinity and calcium concentration to magnesium concentration etc. were calculated and plotted against chlorinity as are demonstrated in Figs. 4 and 5. The variation of the values was discussed from the view-point of geochemistry.

II. Geographic Condition of Susaki Bay

Susaki Bay is a small inlet with a wide mouth facing south on Tosa Bay. It consists of an inner body of water with an area of 1.28 km^2 and an outer body, which may be regarded as a part of the shore of Tosa Bay. The water in the outer body is in no way different from ocean water. Two rivers flow into this bay: Sakura River into the inner body and another river, Shinjo into the outer body. These rivers cause salinity to fall in the upper layers of sea water. The depth of the bay is about 9 meters in the center of the inner body, 16 meters at the "small," and 12–18 meters in the outer body.

III. Method of Investigation

The authors collected water samples at every meter of depth at the eight observation points shown in Fig. 1. For the measurement of chlorinity they used Mohr's method. Calcium and magnesium were measured as follows: An definite quantity of sea water was titrated with EDTA at PH 10 using E.B.T. as the indicator, and thus the total quantity of the two elements was found. Then, after Mg was precipitated in the form of $Mg(OH)_2$, the filtrate was titrated with EDTA using Dotite NN [2–Hydroxy–1–(2–hydroxy–4 sulfo–1–naphthylazo) –3–naphthoic acid] as the indicator. This gave the quantity of Ca. Deduction of the puantity of Ca from the total quantity gave that of Mg.

IV. Results and Consideration

As a general rule, chlorinity is somewhat lower, being 15–16%, in the upper layers of water than in the bottom layers. This is presumably due to the effect of river water that flows in; but such a water mass of low salinity never goes deeper than 3 meters. Below 3 meters, chlorinity is 18–18.5%.

The vertical distribution of water temperature and chlorinity on October 16, 1957, is shown in Figs. 2 and 3. These diagrams indicate that a water mass of low temperature and low salinity occupies the upper layers, and that a water mass of high temperature and high salinity is found in the inner parts of the bay, and that the water mass in the regions adjacent to the outer ocean has, again, low temperature and low salinity.

The fact that, from point F toward the outer ocean, there is a water mass of comparatively low temperature and salinity, may be accounted for by the Shinjo River emptying into the outer body.

In the neighborhood of point E and F, where the above-mentioned three water masses come in contact, there are formed what are called discontinuous layers. Therefore, the discontinuous layers in this bay can be divided into those that form the depth of 1–2 meters and those that form deep down in the center of the tide, and sometimes they may even disappear completely.

Conclusively, the lowering of salinity is to be attributed to the influence of the Sakura and Shinjo rivers; and it is to be presumed that the relatively heigh salinity in the inner parts of the bay is due to the water of the Sakura River mainly affecting to the upper layers which do not mix well with the water of the lower layers.

V. The Ratio of Ca/Cl and Its Variation

The ratio of Ca/Cl is practically the same everywhere in the open sea. Thompson[1] puts it as 0.02090; Machida[2], however, gives 0.02093–0.02193 as the result of his measurement in Tokyo Bay. The general tendency in inlets and near the shore is for the chlorinity to increase. This is probably due to the alteration in the composition of sea water under the influence of land water that flows in.

From the data in Susaki Bay, the authors have tried to see what regularity is to be observed in the variation of chlorinity ratio. It is shown in Fig. 4. In this diagram, the logarithms of chlorinity ratio are plotted against chlorinity, and it is seen that the chlorinity ratio tends to increase as the chlorinity decreases, and that in a stable water mass the logarithms are distributed roughly on a straight line. This means that the composition of sea water undergoes a regular variation by the mixing of land water. When the mole ratio of Ca to Mg is plotted against chlorinity in the same way, we get a sort of tendency shown in Fig. 5. That is to say, the mole ratio increases as the chlorinity decreases, and the relation between them is represented by an almost

straight line. However, the mole ratio of Ca to Mg in river water in this prefecture is 3–4 for the most part, but in the sea water in Susaki Bay it is 0.19. In order to explain the difference in ratios, it is needed to investigate further on the inlet where the sea water is diluted on a large scale; and the investigation is now being carried on in Urado Bay, which is a land-water type of inlet.

That the relation between the logarithm of the chlorinity ratio of Ca to chlorinity can be expressed roughly in a straight line may mean that Ca is comparatively quick in varying its composition. (cf. Figs. 4 and 5.)

In a part of the surface water and of the water in the bottom layers, extreme deviation from the straight line is often encountered, and this always takes place in an unstable water mass.

VI. Summary

The authors have tried to make clear the distribution of temperature and chlorinity in Susaki Bay, and have shown that there are three distinct water masses in this inlet. They have also proved that there is a regularity in the variation of chlorinity ratio of Ca. It seems that the some tendency will be

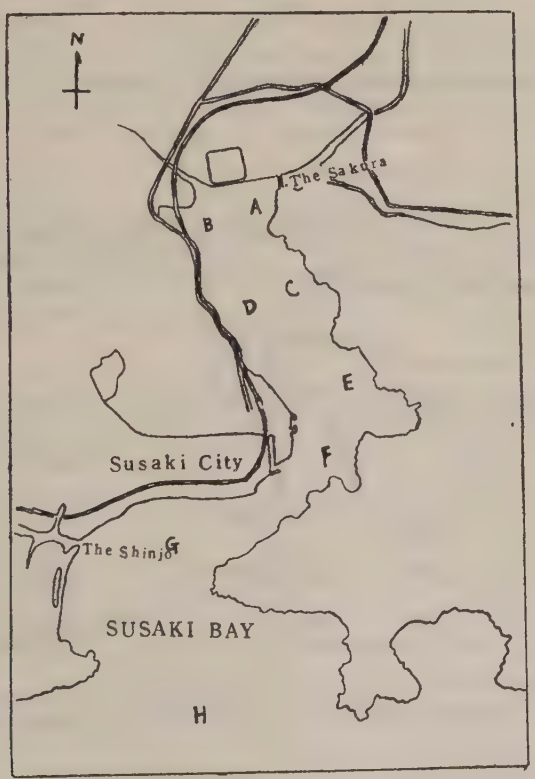

Fig. 1. Observation Stations in Susaki Bay.

found in regard to Mg, on which the authors expect to present a report in the future.

The deepest thanks of the authors are due to Professer Masayoshi Ishibashi of the Faculty of Science, Kyoto University, for his collaboration.

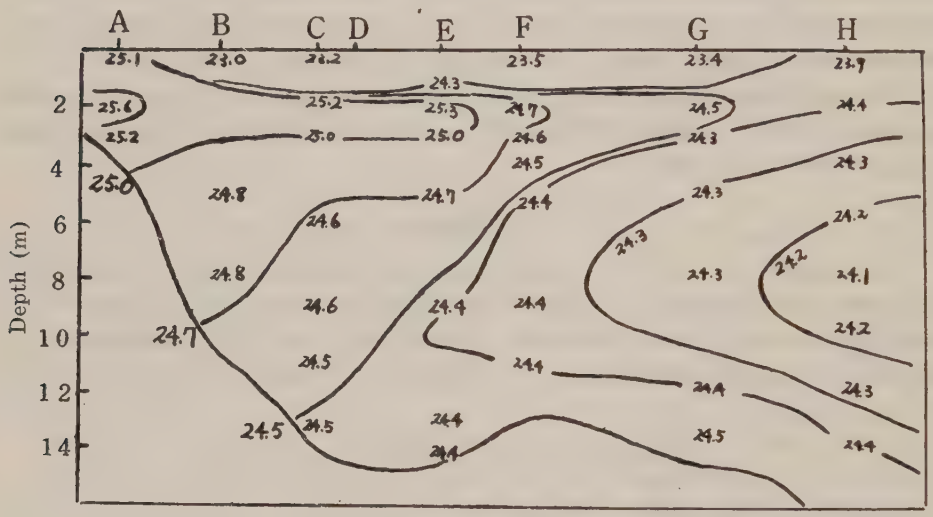

Fig. 2. Vertical distribution of water temperature in Susaki Bay.

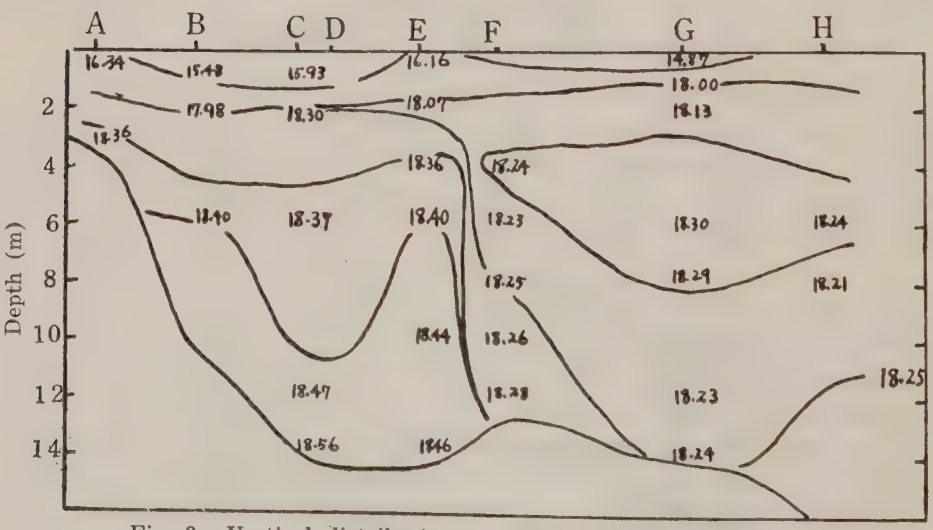

Fig. 3. Vertical distribution of chlorinity in Susaki Bay.

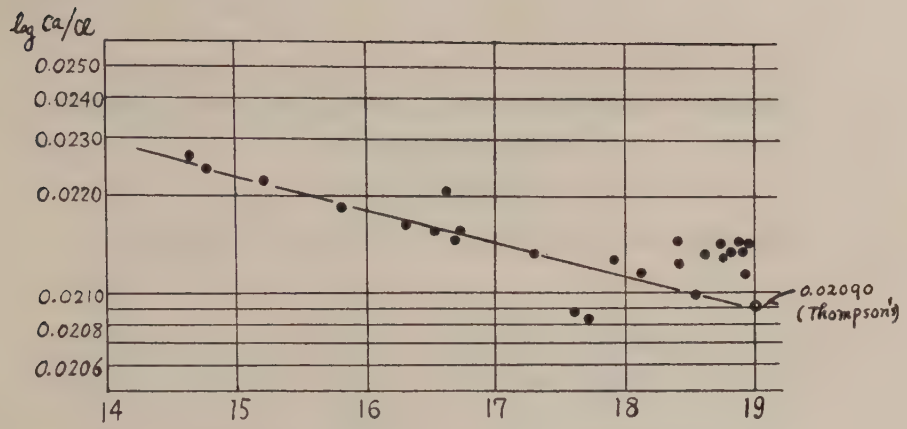

Fig. 4. Relation between chlorosity and calcium-chlorinity ratio.

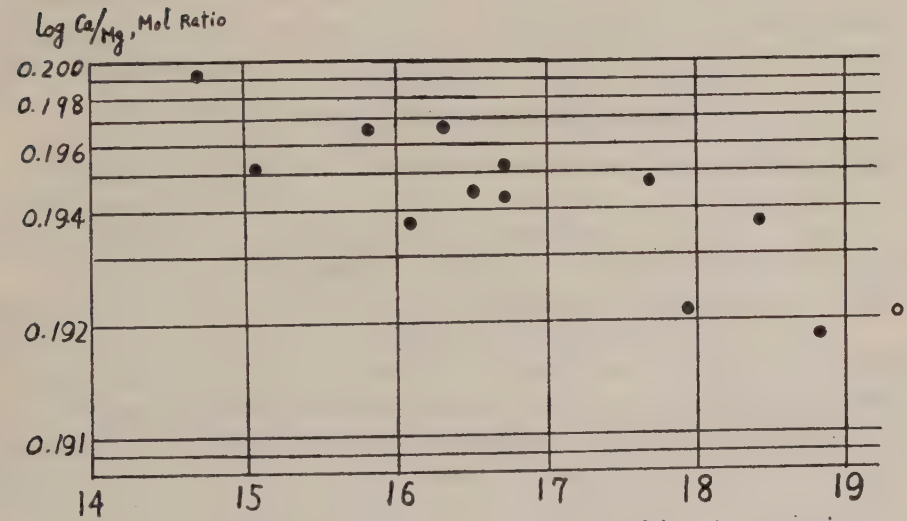

Fig. 5. Relation between chlorosity and ratio of calcium to magnesium.

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STUDIES ON THE UTILIZATION OF THE SHALLOW-WATER DEPOSITS
(Continued)

On the Zinc Content of the Shallow-water Deposits

By

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Introduction

In the previous paper[1], the authors gave the copper content of 166 shallow-water deposits collected at the sea-coasts of Korea and Honshū Island. In this paper there is given the zinc content of 139 of the same samples. Furthermore, the analytical results of the deposits from various small islands having relatively simple geological structure are also given.

Experimental Procedure and Results

The determination of zinc was carried out mainly by the dithizone method of E.B. Sandell[2].

(1) Zinc Content of the Shallow-water Deposits.

The zinc content of the deposits is shown in Table 1, in which the copper content[1] is also cited for the purpose of showing the relation of zinc to copper. The figures are shown on the sea-salt-free and dry basis.

From Table 1, it is seen that the zinc content is considerably high in Samples 27 and 31 collected in Hiroshima Prefecture, Samples 51 and 52 from Okayama, Samples 57 and 59 from Yamaguchi and Sample 87 from Kanagawa, while it is exceedingly low in Sample 21 from Aichi, Sample 71 from Hyōgo, Sample K 5 from Hwanghae-do and Sample K 21 from Kangwon-do.

Summarizing the data in Table 1, we obtained the figures shown in Table 2, which shows that the averages of Honshū are higher than those of Korea in both sands and muds. And it is observed that the average zinc content is everywhere higher in muds than in sands. Comparing these figures with those obtained by other investigators, the total averages of Honshū and Korea are lower than that of 22 red clays of the Pacific, which is 0.037%, and that of 64 deposits of the Japan Sea, 0.0117%, by M. Tatsumoto[3], and are higher than that of red clays*,

* composite of 51 red clays.

0.0042%, by Clarke[4]. The Korean figure is about equal to that of terrigenous clays*, 0.0056% reported by Clarke[4], and the Honshū figure is higher than either of them.

There is some tendency of the zinc content being paralleled by the copper content, though with many exceptions. The Cu:Zn ratio ranges from 0 to 1.23 (mean:0.20) for the Honshū samples and from 0.02 to 3.50 (mean: 0.34) for the Korean.

Between the zinc content and the amounts of common elements, there seems to be no definite relation applicable to all the samples. Though there are many exceptions, it is seen that the zinc content is high in the deposits which are poor in SiO_2 and rich in Fe_2O_3, MgO, S, etc.

(2) Relation between the Zinc Content and the Geology.

In order to investigate the relation between the zinc content and geology, the authors analysed some deposits from various small islands** having relatively simple geological structure and unlikely to be influenced by the geology of remote places.

The analytical results are shown in Table 3, in which the copper content[1] is also cited. The figures are shown on the sea-salt-free and dry basis.

In the deposits of the group of islands Hiroshima through Kajishima in the list, where igneous rocks predominate, the zinc content ranges from 23 to 96 p.p.m., and there is no marked difference between acidic and basic rocks. The deposits between Kasatoshima and Nushima, where the metamorphic rocks predominate, are richer in zinc than the deposits from the former islands, the figure being especially high in Kasatoshima. As for the sedimentary rocks, the zinc content is high in those of Mesozoic formations which are mostly composed of shale, probably deposited in rather deep seas, while it is considerably low in Paleozoic formations.

Results of Table 3 are summarized in Table 4.

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* composite of 52 terrigenous clays.
** Three capes are also included.

Table 1. Zinc content of the shallow-water deposits.

Sample No.	Locality	Type of deposits	Zn content 10^{-4} %	Cu content 10^{-4} %	Cu/Zn
1	Ataka-machi, Komatsu-shi, Ishikawa-ken	light brown sand	42	3	0.07
2	Mukōawagasaki, Uchinada-mura, Kahoku-gun, Ishikawa-ken	brown sand	91	7	0.08
3	Takahama, Takahama-machi, Hakui-gun, Ishikawa-ken	light brown sand	37	4	0.11
4	Ōkawa, Machino-machi, Fugeshi-gun, Ishikawa-ken	blackish sand	93	21	0.23
5	Fujinami, Sannami-mura, Fugeshi-gun, Ishikawa-ken	blackish sand	22	10	0.45
6	Mattō, Nanao-shi, Ishikawa-ken	light grayish brown sand	63	11	0.17
7	Kubo, Kubo-mura, Himi-gun, Toyama-ken	light brown sand	69	5	0.07
8	Ebie, Ebie-mura, Imizu-gun, Toyama-ken	light grayish brown sand	58	4	0.07
9	Shimomuraki-machi, Uozu-machi, Shimoniikawa-gun, Toyama-ken	light yellowish sand	74	5	0.07
10	Ikuji-machi, Shimoniikawa-gun, Toyama-ken	small gravel	n.d.	n.d.	—
11	Shimoarahama, Yachiho-mura, Nakakubiki-gun, Niigata-ken	grayish white sand	79	12	0.15
12	Kujiranami, Kashiwazaki-shi, Niigata-ken	blackish brown sand	69	9	0.13
13	Amaze, Izumozaki-machi, Santō-gun, Niigata-ken	brown sand	75	8	0.11
14	Kawakami, Ikarashihama, Uchino-machi, Nishikambara-gun, Niigata-ken	grayish white sand	63	16	0.25
15	Muramatsuhama, Matsuzuka-mura, Kitakambara-gun, Niigata-ken	grayish white sand	75	8	0.11
16	Aburato, Kamo-machi, Nishitagawa-gun, Yamagata-ken	grayish sand	100	17	0.17
17	Miyaumi, Nishiarase-mura, Akuumi-gun, Yamagata-ken	grayish white sand	63	4	0.06
18	Yoshigo, Tahara-machi, Atsumi-gun, Aichi-ken	grayish green fine mud	107	23	0.21
19	Ura, Tahara-machi, Atsumi-gun, Aichi-ken	grayish green fine mud	91	19	0.21
20	Namiirie, Oitsu-mura, Atsumi-gun, Aichi-ken	grayish green sandy mud	69	11	0.16
21	Nakane, Terazu-machi, Hazu-gun, Aichi-ken	grayish green sandy mud	14	4	0.29
22	Yoshihama, Takahama-machi, Hekikai-gun, Aichi-ken	grayish green fine mud	138	28	0.20
23	Ishikiri, Kamezaki, Handa-shi, Aichi-ken	grayish green sandy mud	n. d.	n. d.	—
24	Nawa, Ueno-machi, Chita-gun, Aichi-ken	grayish green mud	107	9	0.08

25	Sankaku, Shimonoishiki-machi, Nakagawa-ku, Nagoya-shi, Aichi-ken	grayish green fine mud	98	22	0.22
26	Shingai-machi, Fukuyama-shi, Hiroshima-ken	grayish green fine mud	137	28	0.20
27	Minomi-machi, Numakuma-gun, Hiroshima-ken	grayish green fine mud	161	28	0.17
28	Yoshiwa-machi, Onomichi-shi, Hiroshima-ken	grayish green mud	40	16	0.40
29	Nouji, Saizaki-machi, Toyota-gun, Hiroshima-ken	yellowish white sand	78	6	0.08
30	Miyatoko, Tadanoumi-machi, Toyota-gun, Hiroshima-ken	light brown sand	50	2	0.04
31	Kitazaki, Takehara-machi, Kamo-gun, Hiroshima-ken	grayish green fine mud	274	240	0.88
32	Kirasaki, Shimono-mura, Kamo-gun, Hiroshima-ken	grayish green mud	148	25	0.17
33	Mitsu, Akitsu-machi, Kamo-gun, Hiroshima-ken	light grayish brown sand	24	2	0.08
34	Tsukimigahama, Itsukaichi, Itsukaichi-machi, Saeki-gun, Hiroshima-ken	light brown sand	53	6	0.11
35	Karasumori, Uchimichikawa, Michikawa-mura, Yuri-gun, Akita-ken	grayish white sand	54	8	0.15
36	Shimodeto, Tennō-mura, Minamiakita-gun, Akita-ken	brown sand	128	11	0.09
37	Minamihirasawa, Funagawaminato-machi, Minamiakita-gun, Akita-ken	grayish white sand	32	8	0.25
38	Miyasawa, Katanishi-mura, Minamiakita-gun, Akita-ken	brown sand	86	12	0.14
39	Kohama, Kurosaki, Iwasaki-mura, Nishitsugaru-gun, Aomori-ken	grayish white sand	68	trace	0
40	Isouchi, Rokumaibashi, Ushirogata-mura, Higashitsugaru-gun, Aomori-ken	blackish sand	104	6	0.06
41	Asadokoro, Kominato-machi, Higashitsugaru-gun, Aomori-ken	grayish sand	76	18	0.24
42	Uwano, Ōhata, Ōhata-machi, Shimokita-gun, Aomori-ken	brown sand	71	5	0.07
43	Tomari, Rokukasho-mura, Kamikita-gun, Aomori-ken	blackish brown sand	101	5	0.05
44	Hitokawame, Momoishi-machi, Kamikita-gun, Aomori-ken	blackish sand	122	9	0.07
45	Tamakawa, Noda-mura, Kunohe-gun, Iwate-ken	grayish white sand	59	16	0.27
46	Fujiwara, Miyako-shi, Iwate-ken	blackish sand	51	16	0.31
47	Tsugaruishi-mura, Shimohei-gun, Iwate-ken	grayish white sand	55	9	0.16
48	Orikasa-mura, Shimohei-gun, Iwate-ken	dark grayish sandy mud	64	25	0.39
49	Akasawa, Ōfunato-machi, Kesen-gun, Iwate-ken	blackish sand	62	13	0.21

50	Okiura, Higashikatakami, Katakami-machi, Wake-gun, Okayama-ken	dark grayish green fine mud	130	67	0.52
82	Awarigō, Nagahama-mura, Oku-gun, Okayama-ken	grayish green sandy mud	109	120	1.10
51	Nishitakasaki, Nadasaki-mura, Kojima-gun, Okayama-ken	grayish green fine mud	169	28	0.17
52	Nishitakasaki, Nadasaki-mura, Kojima-gun, Okayama-ken	grayish green fine mud	167	11	0.07
53	Ōsaki, Hachihama-machi, Kojima-gun, Okayama-ken	grayish green fine mud	136	20	0.15
54	Hachihama-machi, Kojima-gun, Okayama-ken	grayish green mud	138	10	0.07
55	Yorishima-machi, Asaguchi-gun, Okayama-ken	grayish green mud	103	15	0.15
56	Yōsuna, Kanaura-machi, Oda-gun, Okayama-ken	grayish green mud	107	15	0.14
57	Yanai-machi, Kuga-gun, Yamaguchi-ken	grayish green mud	172	28	0.16
58	Shinzaki, Higashitoyoi, Kudamatsu-shi, Yamaguchi-ken	grayish white sand	31	9	0.29
59	Ninomasu, Nakanoseki-machi, Hōfu-shi, Yamaguchi-ken	yellowish white sand	174	14	0.08
60	Kiwaura, Higashikiwa-mura, Yoshiki-gun, Yamaguchi-ken	yellowish white sand	42	4	0.10
61	Matsuoda, Shimonoseki-shi, Yamaguchi-ken	light brownish gray sand	133	7	0.05
62	Ōhibi, Senzaki-machi, Ōtsu-gun, Yamaguchi-ken	light brown sand	132	12	0.09
63	Uku, Nago-machi, Abu-gun, Yamaguchi-ken	grayish sand	28	3	0.11
64	Asari-mura, Naka-gun, Shimane-ken	yellowish white sand	23	9	0.39
65	Yasugi, Yasugi-machi, Nogi-gun, Shimane-ken	brown sand	55	4	0.07
66	Yoshizu, Sakitsu-mura, Saihaku-gun, Tottori-ken	grayish sand	90	12	0.13
67	Ōshinozu-mura, Saihaku-gun, Tottori-ken	yellowish white sand	56	16	0.29
68	Yodoe, Yodoe-machi, Saihaku-gun, Tottori-ken	grayish sand	139	20	0.14
69	Ajiro-mura, Iwami-gun, Tottori-ken	light brown sand	140	172	1.23
70	Ōkura-machi, Akashi-shi, Hyōgo-ken	yellowish white sand	59	12	0.20
71	Shinzaike, Aboshi-ku, Himeji-shi, Hyōgo-ken	grayish brown sand	18	11	0.61
72	Naba-machi, Aioi-shi, Hyōgo-ken	grayish green mud	92	26	0.28
73	Naba-machi, Aioi-shi, Hyōgo-ken	grayish green mud	117	32	0.27
74	Miwasaki-machi, Shingū-shi, Wakayama-ken	blackish gray sand	65	18	0.28
75	Hosono, Katata, Nishitonda-mura, Nishimuro-gun, Wakayama-ken	light brown sandy mud	49	11	0.22

76	Kitahara, Shinjō-mura, Nishimuro-gun, Wakayama-ken	light brown sandy mud	57	9	0.16
77	Minabe-machi, Hidaka-gun, Wakayama-ken	brown sand	55	12	0.22
78	Enokoma, Yura-machi, Hidaka-gun, Wakayama-ken	light brown sand	91	5	0.05
79	Ōyodo, Ōyodo-machi, Take-gun, Mie-ken	light grayish brown sand	24	1	0.04
80	Funakoshi-mura, Shima-gun, Mie-ken	grayish white sandy mud	129	24	0.19
81	Nagashima-machi, Kitamuro-gun, Mie-ken	blackish brown sand	97	12	0.12
83	Suna, Hasunuma-mura, Sanbu-gun, Chiba-ken	light brown sand	63	23	0.37
84	Hama-machi, Anesaki, Anesaki-machi, Ichihara-gun, Chiba-ken	blackish gray sand	24	2	0.08
85	Hon-machi, Funabashi-shi, Chiba-ken	light blackish brown sand	92	10	0.11
86	Kanazawa-machi, Isogo-ku, Yokohama-shi, Kanagawa-ken	grayish sand	99	8	0.08
87	Ōiso, Ōiso-machi, Naka-gun, Kanagawa-ken	blackish sand	154	71	0.46
88	Sakawa, Sakawa-machi, Ashigaranoshimo-gun, Kanagawa-ken	blackish sand	125	45	0.36
89	Usami-mura, Tagata-gun, Shizuoka-ken	blackish brown sand	87	15	0.17
90	Tago, Tagonoura-mura, Fuji-gun, Shizuoka-ken	blackish gray sand	95	21	0.22
91	Chihama, Chihama-mura, Ogasa-gun, Shizuoka-ken	light blackish gray sand	42	7	0.17
92	Hamana, Arai-machi, Hamana-gun, Shizuoka-ken	light blackish gray sand	22	6	0.27
111	Namiita, Shishiori-mura, Motoyoshi-gun, Miyagi-ken	grayish sandy mud	50	41	0.82
93	Namiita, Shishiori-mura, Motoyoshi-gun, Miyagi-ken	grayish mud	134	78	0.58
94	Shizukawa-machi, Motoyoshi-gun, Miyagi-ken	grayish white sand	99	6	0.06
95	Ōmagari, Yamoto-machi, Monou-gun, Miyagi-ken	light brown sand	97	9	0.09
96	Nakahama, Sakamoto, Sakamoto-mura, Watari-gun, Miyagi-ken	light yellowish gray sand	53	3	0.06
97	Shin-machi, Ukedo, Ukedo-mura, Futaba-gun, Fukushima-ken	light brownish gray sand	87	2	0.02
98	Naka-machi, Yotsukura-machi, Iwaki-gun, Fukushima-ken	light yellowish gray sand	48	4	0.08
99	Kawajiri, Toyoura-machi, Taga-gun, Ibaraki-ken	light brownish gray sand	50	7	0.14
100	Akashi, Namino-mura, Kashima-gun, Ibaraki-ken	light brownish gray sand	66	5	0.08
101	Yoshimi, Tajiri-mura, Sennan-gun, Ōsaka-fu	yellowish brown sand	67	3	0.04
110	Kamiya-machi, Kishiwada-shi, Ōsaka-fu	yellowish brown sand	69	10	0.14

102	Shiomi-machi, Izumiōtsu-shi, Ōsaka-fu	light yellowish brown sand	54	18	0.33
103	Hamazume-mura, Takeno-gun, Kyōto-fu	light brown sand	58	11	0.19
104	Iwagahana, Yōrō-mura, Yoza-gun, Kyōto-fu	light brown sand	133	6	0.05
109	Shimasaki, Miyazu-machi, Yoza-gun, Kyōto-fu	yellowish brown sand	79	14	0.18
105	Higashikanzaki, Kanzaki-mura, Kasa-gun, Kyōto-fu	light brownish gray sand	55	12	0.22
106	Wakamiya, Takahama-machi, Ōi-gun, Fukui-ken	greenish black sand	74	8	0.11
107	Shirahige, Obama-machi, Onyū-gun, Fukui-ken	grayish brown sand	74	15	0.20
108	Ishishinbo, Natsume-mura, Sakai-gun, Fukui-ken	brown sand	42	1	0.02
K 1	Puna, Yongchon-kun, Pyongan-Pukto	dark brown mud	n. d.	n. d.	—
K 2	Osong-tong, Taesan-myon, Sonchon-kun, Pyongan-pukto	dark brown mud	51	3	0.06
K 3	Hampal-ri, Hanchon-myon, Pyongwon-kun, Pyongan-namdo	dark brown mud	53	10	0.19
K 4	Okyangki-ri, Chinnampopu, Pyongan-namdo	dark brown mud	71	27	0.38
K 5	Yonghoto-ri, Tongnam-myon, Ongjin-kun, Hwanghae-do	dark brown mud	2	7	3.50
K 6	Chinjong-ri, Sonwon-myon, Kanghwa-kun, Kyonggi-do	dark brown mud	26	7	0.27
K 7	Tongjoung-ri, Soukmun-myon, Tangjin-kun, Chungchong-namdo	dark brown mud	51	21	0.41
K 8	Sopinchon, Kunsanpu, Cholla-pukto	dark brown mud	84	35	0.42
K 9	Namchang-ri, Pukpyong-myon, Haenam-kun, Cholla-namdo	dark brown mud	27	12	0.44
K 10	Mayang-ri, Taeku-myon, Kangjin-kun, Cholla-namdo	dark brown mud	124	12	0.10
K 11	Haean, Kuhangshine, Yosu-ub, Yosu-kun, Cholla-namdo	dark brown mud	139	64	0.46
K 12_1	Royang-ri, Kumnan-myon, Hadong-kun, Kyongsang-namdo	dark brown sandy mud	54	19	0.35
K 12_2	Royang-ri, Kumnan-myon, Hadong-kun, Kyongsang-namdo	dark brown mud	46	11	0.24
K 13	Sonjin-ri, Yongkyoun-myon, Sachon-kun, Kyongsang-namdo	dark brown sandy mud	23	10	0.43
K 14	Tupu-ri, Samsan-myon, Kosong-kun, Kyongsang-namdo	dark brown mud	63	16	0.25
K 15	Shinjon-ri, Sanyang-myon, Tongyong-kun, Kyongsang-namdo	dark brown sandy mud	68	13	0.19
K 16	Kyonghwa-tong, Chinhae-ub, Changwon-kun, Kyongsang-namdo	brown mud	92	47	0.51
K 17	Chedok-ri, Ungchon-myon, Changwon-kun, Kyongsang-namdo	dark brown mud	39	16	0.41

K 18	Bangou-ri, Tong-myon, Ulsan-kun, Kyongsang-namdo	yellow clay	68	19	0.28
K 19_1	Pohang-tong, Pohang-ub, Yongil-kun, Kyongsang-pukto	dark brown mud	121	25	0.21
K 19_2	Pohang-tong, Pohang-ub, Yongil-kun, Kyongsang-pukto	light yellowish brown sand	56	1	0.02
K 20	Imwon-ri, Wondok-myon, Samchok-kun, Kangwon-do	light yellowish brown sand	22	7	0.32
K 21	Chumun-ri, Chumunjin-myon, Kangnung-kun, Kangwon-do	yellowish white sand	18	4	0.22
K 22	Haean-tong, Wonsanpu, Hamgyong-namdo	light yellowish brown sand	52	3	0.06
K 23	Hengchon, Songjin-ub, Songjin-kun, Hamgyong-pukto	light brown sand	61	11	0.18
K 24	Songshin-tong, Ouyang-myon, Kyongsong-kun, Hamgyong-pukto	light brown sand	45	1	0.02
K 25	Tokyoun-tong, Ochon-myon, Kyongsong-kun, Hamgyong-pukto	grayish white sand	93	10	0.11
K 26_1	Bipa-tong, Songpyong-tong, Unggi-ub, Kyonghung-kun, Hamgyong-pukto	grayish white sand	38	2	0.05
K 26_2	Ungsang-tong, Unggi-ub, Kyonghung-kun, Hamgyong-pukto	light yellowish brown sand	50	4	0.08
K 26_3	Unggi-tong, Unggi-ub, Kyonghung-kun, Hamgyong-pukto	grayish white sand	36	4	0.11
K 27	Sosura-tong, Roso-myon, Kyonghung-kun, Hamgyong-pukto	grayish white sand	108	4	0.04

Table 2. Summary of Table 1.

Number of samples		Zn content (10^{-4} %)	
		Range	Average
Total samples from Honshū	109	14 ~ 274	84
Sands	80	18 ~ 174	73
Muds*	29	14 ~ 274	114
Total samples from Korea	30	2 ~ 139	59
Sands	11	18 ~ 108	53
Muds*	19	2 ~ 139	63

* Sandy muds and clay are also included.

Table 3. Zinc content of the shallow-water

Locality	Geology**	Type of deposits
Hiroshima, Kagawa-ken	Granites	grayish white sand
Nakashima, Ehime-ken	Granites	light brown sand
Ogishima, Kagawa-ken	Granites (Sanukite)	light brown sand
Momoshima, Hiroshima-ken	Granites	light brown sand
Yokoshima, Hiroshima-ken	Granites	light brown sand
Okinoshima, Kōchi-ken	Granites	grayish brown sand
Kogoshima, Ehime-ken	Granites	brown sand
Kōnoshima, Okayama-ken	Quartz-porphyry	light brown sand
Tashima, Hiroshima-ken	Quartz-porphyry (Granites, Ryōke metamorphics)	greenish sandy mud
Hēgunshima, Yamaguchi-ken	Pyroxene-andesite	grayish brown sand
Kajishima, Ehime-ken	Norite	light blackish gray sand
Kasatoshima, Yamaguchi-ken	Ryōke metamorphics (Granites)	grayish brown sandy mud
Ōtsushima, Yamaguchi-ken	Sangun metamorphics (Granites)	blackish green sand
Takashima, Ōita-ken	Sanbagawa metamorphics	grayish blue sand
Nushima, Hyōgo-ken	Greenschist, Black phyllite	grayish white sand
Shishishima, Kagawa-ken	Upper Paleozoic formations	light brown sand
Mutsukishima, Ehime-ken	Upper Paleozoic formations (Granites)	yellowish brown sand
Ōnyūshima, Ōita-ken	Mesozoic formations	brown sand
Shimoniizu-mura, Ōita-ken	Mesozoic formations	brown sand
Sugari, Owashi-shi, Mie-ken	Mesozoic formations	blackish gray sand
Tobishima, Yamagata-ken	Tertiary formations	blackish gray sand
Higashitonda-mura, Wakayama-ken	Tertiary formations	light blackish gray sand
Himagashima, Aichi-ken	Tertiary formations	light grayish brown sand

* Three capes are also included.

** Only the predominant rocks and formations are shown. The parentheses are

deposits collected from various small islands*.

Composite of	Zn 10^{-4}%	Cu 10^{-4}%	Cu/Zn	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	MnO %	CaO %	MgO %	CO_2 %
5 deposits	23	trace	0	82.92	0.56	9.23	trace	0.74	0.33	—
5 „	74	3	0.04	79.28	1.26	11.01	0.01	1.09	0.34	—
5 „	25	4	0.16	77.49	1.97	12.16	0.03	2.23	0.24	—
4 „	34	4	0.12	75.81	2.34	12.21	0.04	1.69	0.40	—
5 „	74	4	0.05	76.21	2.49	14.77	0.03	1.32	0.25	—
5 „	68	4	0.06	73.96	3.08	10.40	0.04	3.76	0.46	2.33
3 „	28	4	0.14	70.62	4.28	12.98	0.11	2.85	1.14	1.66
5 „	96	6	0.06	79.24	1.56	9.74	0.02	2.57	0.56	1.28
5 „	56	9	0.16	75.87	2.02	11.52	0.03	0.90	0.49	—
2 „	56	8	0.14	71.20	2.98	13.49	0.04	2.92	1.87	—
5 „	74	9	0.12	52.64	8.25	20.06	0.18	9.69	4.58	0.52
4 „	145	19	0.13	79.36	3.05	6.82	0.11	2.82	1.12	1.58
2 „	68	18	0.26	47.48	6.14	12.31	0.12	15.95	2.74	8.28
5 „	85	25	0.29	70.02	2.87	9.51	0.06	7.05	1.86	4.01
5 „	90	11	0.12	74.26	2.16	7.07	0.06	5.62	0.74	3.86
5 „	18	3	0.17	87.54	1.00	5.77	0.04	1.19	0.21	—
2 „	11	7	0.64	79.25	1.02	10.05	0.01	2.13	0.52	—
4 „	72	15	0.21	76.42	2.99	10.95	0.03	1.80	0.26	0.50
5 „	112	30	0.27	70.67	5.21	13.37	0.08	0.76	1.10	—
4 „	85	19	0.22	72.20	3.38	11.27	0.04	3.45	0.65	1.20
4 „	94	2	0.02	57.69	3.69	14.82	0.05	8.56	2.20	5.14
4 „	62	14	0.23	56.25	2.76	7.15	0.01	15.27	1.25	11.28
5 „	64	10	0.16	77.54	1.79	8.77	0.01	3.83	0.51	2.18

for the rocks which distribute in the land areas relatively far from the location sampled.

Table 4. Zinc content and the geology (summary of Table 3).

Geology	Number of samples	Zn content (10^{-4} %)	
		Range	Average
Igneous rocks			
Acidic rocks	9	23 ~ 96	53
Basic rocks	2	56 ~ 74	65
Metamorphic rocks			
Gneisses	1	—	145
Crystalline schists	3	68 ~ 90	81
Sedimentary rocks			
Upper Paleozoic formations	2	11 ~ 18	15
Mesozoic formations	3	72 ~ 112	90
Tertiary formations	3	62 ~ 94	73

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STUDIES ON THE INORGANIC CHEMICAL CONSTITUENTS OF SEA FISHES

(Part I)

By

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1. Introduction

This studies aim to investigate how the chemical elements contained in the sea water are distributed or condensed in the body of sea fishes, and to obtain the materials regarding what is the role of these elements in the living body, what fishes or what portions of fishes are useful as nutrition, and so on.

On the other hand, the author hopes that this studies can add some contributions to the geochemical knowledge of the biosphere of the earth.

2. Deep-sea Fishes

2. 1. Samples and their treatments

Samples are the sea fishes which were caught at 200–300 meters in depth of the Bay of Tosa, Kochi prefecture, Japan.

Fishes studied here are indicated in the Table 1.

Preparation of Samples

Larger fishes were separated to three parts: inner organs, fish and bone; but smaller fishes as a whole were analized, respectively.

Inner organs were reduced to ash by the wet method, and the other parts by the dry method.

Raw fishes were well washed by water to clean off the sea water, sands and dusts which stained the surfaces, and internal organs especially stomach and bowels were washed thoroughly and the contents all taken off.

Then they were dried and burnt to ashes at about 550°C in an electric muffle furnace.

Table 2 indicates the decrease in the weight which followed to dry and to be reduced to ashes.

2. 2. Inorganic constituents of the ashes obtained from deep-sea fishes

Table 3. indicates the results of spectrographic analysis of the ashes. Besides, there were found some appreciable amounts of Chlorine and traces of Bromine and Iodine by the paper chromatographic analysis.

PO_4^{3-}, SO_4^{--} and CO_3^{--} were also detected.

Table 1.

Name of Fishes (Native Name)	Brief Features
Zenion japonicum KAMOHARA (Sokomatodai)	Body 3–4 cm. in length Color reddish yellow Eyes are large for the other parts of body
Chlorophthalmus albatrossis albatrossis JORDAN & STARKS (Aome-eso)	Body 10–15 cm. in length slender fish
Areliscus interruptus (GÜNTHER) (Gencho)	Body 10–20 cm. in length like the flat fish
Gephyroberyx japonicus (DÖDERLEIN) (Hashikinme)	Body 15–20 cm. in length 7–9 cm. in breadth Color reddish yellow
Synagrops Japonica (STEINDACHNER & DÖDERLEIN) (Sumikuiuo)	Body 10–15 cm. in length slender fish
Etmopterus lucifer JORDAN & SNYDER (Fujikujira)	Body 25–35 cm. in length osseous, luciferous
Rexea prometheoides (BLEEKER) (Kagokamasu)	Body 15–20 cm. in length slender fish
Lophius litulon JORDAN (Ankô)	Body about 50 cm. in length ab. 2 kg. in weight Mouth is large for the other parts of body

Table 2.

Name of Fish	Samples	Raw State	Dry State	Char	Ash
Lophius litulon (Ankô)	Bone	100	13–15 (100)	10–12	5–6 (38)
	Fish	100	(100)	3–8	1–3 (14)
Etmopterus lucifer (Fujikujira)	Body except inner Organs	100	12	7	1.5
Areliscus interruptus (Gencho)	Total Body				
Rexea prometheoides (Kagokamasu)	Body except inner Organs		100		14
Synagrops Japonica (Sumikuiuo)	Body except inner Organs				
Zenion japonicum (Sokomatodai)	Total Body		100		18–20
Chlorophthalmus albatrossis albatrossis (Aome-eso)					

Table 3. Results of Spectrographic Analysis of the Ashes of Deep-sea Fishes

Name of Fishes	Samples	Cu	Pb	Sn	Fe	Al	Mn	Zn	Ca	Mg	Na	K	Si	P
Zenion japonicum (Sokomatodai)	Total Body	2•	1•	1	1	tr.	1	—	5	2	5	3	1	2
Chlorophthalmus albatrossis albatrossis (Aome-eso)		4	3	2	2	1	1	—	5	2•	5	3	1•	2•
Areliscus interruptus (Gencho)		2	1	1•	1	tr.	2	—	4	1•	5	4	tr.	2
Gephyroberyx japonicus (Hashikinme)	Body except inner Organs	2	1	1•	1	tr.	tr.	—	5	2•	5	4	tr.	2
Synagrops Japonica (Sumikuiuo)		2	tr.•	1•	1•	tr.	1	—	5	2•	5	4	1•	2•
Etmopterus lucifer (Fujikujira)		2	tr.•	1•	1•	2	1	—	5	2•	5	4	1•	2•
Rexea prometheoides (Kagokamasu)		2	tr.	tr.	1•	1	tr.	—	5	2	5	4	1•	2•
Gephyroberyx japonicus (Hashikinme)	Internal Organs	1•	tr.	1•	1•	1	—	—	4	3	3	1•	2•	2•
Synagrops japonica (Sumikuiuo)		2•	1	1	2	2•	2	—	5	3•	5	3	3	3
Etmopterus lucifer (Fujikujira)		2	1	tr.	3	2•	2	—	5	3	5	4	3	3
Rexea prometheoides (Kagokamasu)		2•	1	1	2	2	2	—	5	3•	5	3	3	3
*Chlorophthalmus albatrossis albatrossis (Aome-eso)		2	2•	2	4	4	2	1	5	4	5	5	5	3
Lophius litulon (Ankô)	Bone	2	tr.•	1•	1	—	1	—	5	2	5	3	—	1•
	Fish	2	tr.	1	2	2	2	—	4	3	5	4	2	2
	*Inner Organs	3•	1•	2•	2	3	1•	-	5	5	5	5	3	4

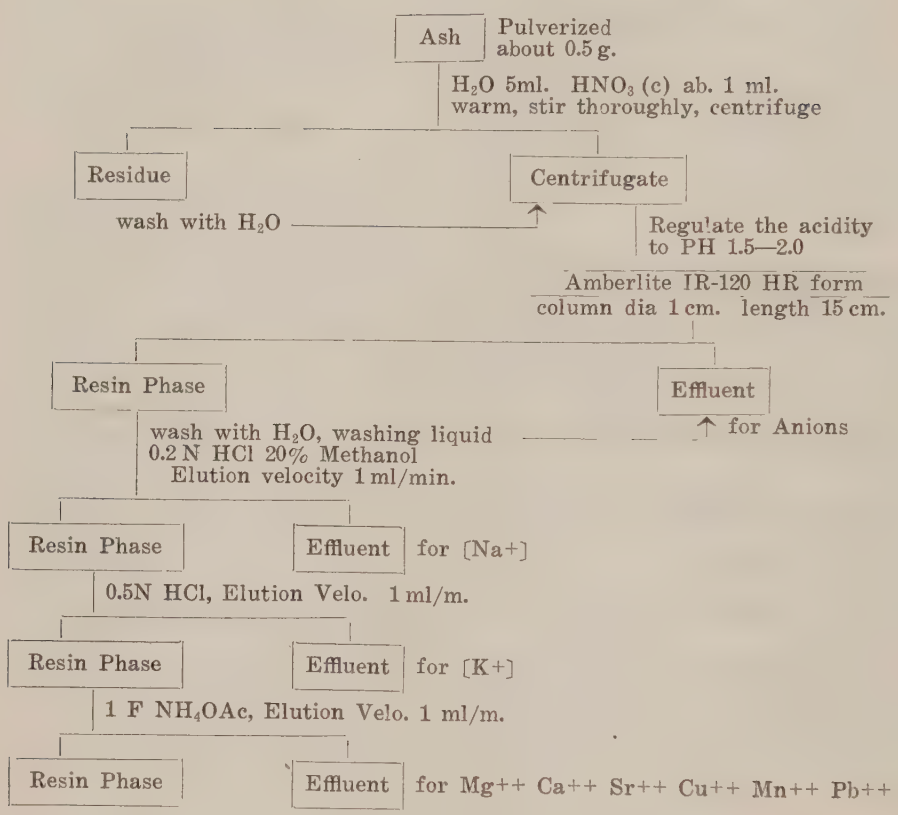
Conditions: Pulsating Current Arc; Voltage: AC 220 v; Curr: 5 Amp.; Breadth of Slit: 0.005 mm.; Height of Slit: 3 mm.; Time of Exposure: 40 sec.; Distance of Electrodes: 2 mm.; Apparatus: Shimazu Spectrograph QF–60 Type.
* Curr: 6 Amp.; Time of Exposure: 30 sec..
Figures indicate roughly quantities of chemical elements.

2. 3. On the relative quantities of alkaline earth elements and alkaline elements contained in ashes of deep-sea fishes.

2. 3. 1. Outline of Analysis

As the amount of ashes obtained from fishes is only a few percent, the method of analysis was planned so that all the constituents may be able to be estimated with the same sample of ash. The outline of the scheme of analysis is found in Table 4.

Table 4. Scheme of Analysis



2. 3. 2. Determination of Sodium and Potassium

Each portion eluted through the ion exchange resin was evaporated to dryness and then heated about 120°C to expel methanol and hydrochloric acid perfectly. This residue was dissolved in water to obtain the solution with suitable concentration for the following procedures.

Na and K were determined by the ion exchange resin method or the flame photometry.

Results from the both methods were almost the same.

2. 3. 3. Determination of alkaline earth elements

These elements were determined by the complexometric titration using EDTA (Ethylendiamine Tetraacetate), and by the flame photometry.

As the eluted solution from ion exchange resin contains Ca, Mg, Sr and some bivalent transition elements such as Cu, Mn etc., it is necessary to add the solution a masking reagent in the case of complexometric titration.

In the flame photometry, the coexisting substances in the sample solution arouse some interference occasionally.

As the luminous intensity of Calcium is decreased by the presence of Ammonium acetate, eluting reagent, the preliminary removing of this salt is important.

Results are indicated in the Table 5.

Table 5. Relative Quantities of Alkaline and Alkaline Earth Elements

Name of Fishes		Ca	Sr	Mg	Na	K	$\frac{\text{Oxide}}{\text{Ash}} \times 100$
Zenion japonicum (Sokomatodai) Total Body	gram-atom $\times 10^3$	6.82	0.027	0.40	2.22	1.50	
	Ratio of g-atom	100	0.39	5.9	32.5	21.6	
	Oxide (g)	0.3790	0.0028	0.0163	0.0686	0.0690	53.5
Chlorophthalmus albatrossis albatrossis (Aome-eso) Total Body	g-atom $\times 10^3$	6.70	0.039	0.51	1.67	1.35	
	Ratio of g-atom	100	0.58	7.7	25.0	20.2	
	Oxide (g)	0.3750	0.0040	0.0206	0.0520	0.0617	51.3
Areliscus interruptus (Gencho) Total Body	g-atom $\times 10^3$	5.29	0.029	0.51	2.30	2.70	
	Ratio of g-atom	100	0.55	9.5	43.2	50.7	
	Oxide (g)	0.2990	0.0031	0.0205	0.0715	0.1270	52.1
Gephyroberyx japonicus (Hashikinme) Body except inner Organs	g-atom $\times 10^3$	7.05	0.039	0.44	1.68	1.77	
	Ratio of g-atom	100	0.55	6.2	23.8	25.2	
	Oxide (g)	0.3960	0.0041	0.0176	0.0520	0.0837	55.4
Synagrops japonica (Sumikuiuo) Body except inner Organs	g-atom $\times 10^3$	6.50	0.042	0.46	1.61	1.98	
	Ratio of g-atom	100	0.64	7.1	24.7	30.5	
	Oxide (g)	0.3640	0.0043	0.0186	0.0495	0.0937	53.0
Etmopterus lucifer (Fujikujira) Body except inner Organs	g-atom $\times 10^3$	5.53	0.033	0.65	3.17	2.36	
	Ratio of g-atom	100	0.59	11.8	57.4	42.7	
	Oxide (g)	0.3110	0.0034	0.0262	0.0985	0.1130	55.0
Lophius litulon (Ankô) Bone	g-atom $\times 10^3$	7.21	0.055	0.78	2.79	0.45	
	Ratio of g-atom	100	0.76	10.8	38.7	6.3	
	Oxide (g)	0.4050	0.0057	0.0314	0.086	0.0213	55.0

The author wishes to thank Dr. M. ISHIBASHI, Prof. of Kyoto University, for helpful directions, Dr. T. KAMOHARA, Prof. Kochi University, for the samples of deep-sea fishes, and the Committee of Marine Productivity of the Japan Science Council.

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STUDIES OF BEACH-SANDS AS CHEMICAL RESOURCES

On Sand-Irons in Beach-Sands along the Coast-line of Tottori Prefecture

By
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Aim: The quantities of rare metals and sand-irons contained in the beach sands are examined, and some components of those sand-irons are investigated. By spectroscopic analysis, it proved that only two of them have a trace of vanadium. The numerals in this report are of the quantities of beach-sands and the components of sand-irons. No radioactivity is found out of them, and the same about those sands gathered from the mouth of the River Tenjin (taking its rise in the back part of Kurayoshi-shi and in the uranium ore district of Ningyō Pass situated at the provincial border of Tottori and Okayama Prefs.).

Gathering of beach-sands and their properties: At first, sands are gathered at the inside of a little delta occupying the estuary of the River Sendai down from Tottori-shi, at the left side of the estuary of the River Kōchi flowing through Hōgi village, at the outside and inside of a delta and at the left side of the River Tenjin, Agei-shi (taking its rise in the uranium ore district of Kogamo and Ningyō Pass), at the left side of the estuary of the River Kaseda, Urayasu (running from Mt. Daisen), at the seashore of Yodoye (the sands gathered there may be considered to be accumulated by natural selection of the flowing sands sent forth from both the Rivers of Amida, east and Hino, west), and finally at the estuary of the River Hino. The possibility of sand-iron project is only for the beach-sands of Yodoye, spreading over several hundreds of meters, of unknown deepness and having the 70% sand-iron. Thus, the seashore is covered with a black color. On the other hand, it was beyond expectation that such a deposit of sand-iron in the offing of Sesaki, Kaka village (situated at the almost midst part of Shimane Peninsula, not in broad area but in an appreciable deepness and in a purer state) was found on the occasion the author worked gathering of sea weeds. The quantities deposited will become obvious by henceforth investigations.

The observed results are summarised in the following table; a given mass of sand-iron was washed with water, dried, weighed and selected with magnet. The radiations were measured with the G. M. type counter of Kōbe-Kōgyō Co..

The number of iron oxide is the difference between the grams of sand-iron selected with magnet and the sum of grams of TiO_2 and SiO_2 analysed.

		Sand-Iron (%)	Radiation Counts (per min.)					(Spectroscopic) (3)		
				Fe_3O_4	Fe	TiO_2	Ti	SiO_2	Si	V
R. Sendai	(outside of delta)	5.98	4	55.06	39.84	8.27	4.46	36.67	17.23	(—)
„ „	(inside of delta)	4.96	4	62.60	45.30	2.35	1.27	35.07	16.47	(—)
R. Kōchi	(west side of delta)	4.70	0	87.63	63.41	7.77	4.19	4.60	2.16	(—)
R. Tenjin	(outside of delta)	5.35	7	29.12	21.07	20.52	11.08	50.36	23.66	(trace)
„ „	(inside of delta)	7.60	5	27.74	20.07	13.74	7.42	58.52	27.50	(trace)
„ „	(west bank)	14.37	4	95.62	69.21	2.98	1.61	1.40	0.65	(trace)
R. Kaseda	(west side of estuary)(1)	17.18	0	92.72	67,11	4.68	3.50	2.58	1.21	(—)
„ „	(„)(2)	27.94	0	92.70	66.74	6.49	3.50	0.81	0.37	(—)
Yodoye Beach		73.20	10	86.11	62.31	6.48	3.47	7.41	3.50	(—)
R. Hino	(west side of estuary)	1.73	6	72.14	52.12	18.23	9.85	9.73	4.57	(trace)
Sesaki	(Shimane Peninsula)	96.73	4	96.34	69.71	0.84	0.47	2.02	1.09	(—)

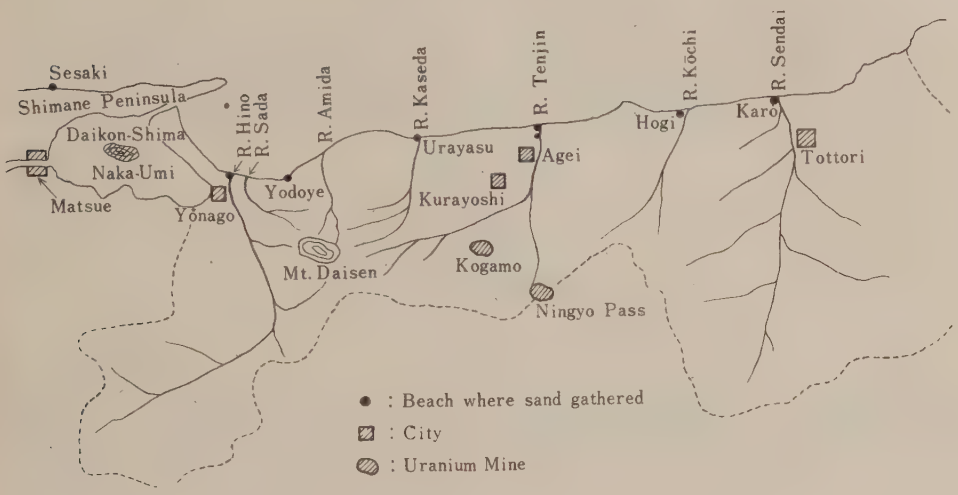
Natural count = 22/min.

By magnetic selection, some amounts of sand happen to be contaminated with sand-iron; thus rather large differences of SiO_2 are often obtained. Accordingly, the observed quantities of TiO_2 are meant to be from both sand and sand-iron respectively. For example, the fact may be seen in those from both the River Tenjin and the River Sendai; and thus the one on the bank of the River Tenjin is, in nature, easily separable with magnet, and the observed results by analysis in the table may show clearly their states. Though the content of the sand-iron of the Yodoye beach-sand is so high, it may be defective that some of sands are apt to be contaminated with sand-iron by magnetic selection, owing to their smallness in size.

The greatness of the proportion of TiO_2 contained in the sand-iron, Hino, may be considered reasonably to come from the sand-iron itself. The sand-iron, Sesaki, is most poor of TiO_2 and so excellent for refining.

After that, the author employed conjugal divers to examine the state of the sea-bed, because the origin of the sand-iron, Sesaki, is obscure and not plausible to exist there, and found that the existing quantities of sand-iron are presumed to be about 400–500 tons. And moreover, they say, two years ago, a

vessel of about one thousand tons in distress off the coast of Sesaki surrendered the most parts of the sand-iron loaded into the sea.



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STUDIES ON MANUFACTURE OF MAGNESIUM HYDROXIDE FROM CALCIUM CARBIDE AND SEA WATER OR BITTER BRINE AND ITS UTILIZATION (Part III)

By
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1. Introduction.

In the previous papers, the author described on conditions of manufacturing $Mg(OH)_2$ with production of C_2H_2 by using CaC_2 as alkali source and discussed on relation between particle sizes for crystallite determined by means of the X ray diffraction line broading method.

As characteristics of this method,

(1) Particle size of $Mg(OH)_2$ by this method is relatively large as well as that prepared with NH_4OH,

(2) Difference of filtration velocity after every time of washing may be concerned with change of ion concentration, because the particle size did not change after washing, and

(3) As to the influence of concentration and temperature, particle size for crystallite grew with the increase of concentration of $MgCl_2$ from 1% to 60% at 20°C, and also of reaction temperature from 20°C to 80°C in 20% solution of $MgCl_2$.

The growth of crystallite according to the increase of concentration may be attributed to slow preparation of crystal caused by retardation of the reaction velocity, as well as the method of adding half equivalent of alkali solution drop by drop to $MgCl_2$ solution which is named "half equivalent method" by us.

The growth of crystallite and increase of filtration velocity according to the increase of reaction temperature may be illustrated by an assumption that owing to decrease of dissociation degree of $Ca(OH)_2$, this reaction proceeds in weak basic solution.

In this paper, relation between particle size for crystallite and filtration velocity of product was investigated under various concentration and temperature, and then was compared the direct method with the indirect method in which the reaction residue $Ca(OH)_2$ obtained with production of C_2H_2 from CaC_2 and water was used instead of CaC_2 in direct method.

As another characteristic of this direct method the author pointed out the fact that preparation of $CaCO_3$ by the reaction of $Ca(OH)_2$ with CO_2 in air and

its mixing into the main product $Mg(OH)_2$ are prevented under production of C_2H_2 and therefore Ca content in the product becomes small. This characteristic of direct method was also compared with indirect method.

2. Comparison between direct and indirect method.

Indirect method, which is $Mg(OH)_2$ manufacturing method from sea water and CaC_2 waste, has been industrialized at Hanshin Magnesia Kogyo Co. in Kobe and others. On the other hand, instead of sea water, bitter brine is used on trial in several works.

C_2H_2 producing works and table salt manufacturing works are in general departed from each other at present, but in future owing to development of electric concentration of sea water those above mentioned two kinds of manufacture would be intimately connected and this indirect method would become of importance.

One of objects of this studies is to determine which process of direct or indirect is superior.

(1) Experimental method.

For comparison of direct with indirect, same equivalent of samples CaC_2 and $MaCl_2$ were used so as to get equal amount of $MgCl_2$ and equal concentration of $CaCl_2$ solution, that is, in indirect method same amount of CaC_2 as in direct method was at first reacted with water to produce C_2H_2, then $MgCl_2$ was dissolved in so less water as the total water was same, and added to the obtained milk of lime. And the product $Mg(OH)_2$ being washed perfectly, its filtration velocity, particle size for crystallite by means of X ray diffractometry and Ca content were compared by same methods as in the previous papers.

(2) Experimental results.

Comparison of filtration velocity (ref. to Table 1).

(A) Filtration velocity increased with the increase of concentration and of temperature in both methods, except in higher concentration (60%) or at higher temperature (80°C). Their difference was not so eminent in indirect method as in direct.

This is illustrated by the fact that in direct method the production of C_2H_2 is restrained in higher concentration, so that the reaction proceeds very slow, but in indirect method this reaction always finishes in same time without influence of concentration.

(B) Exactly to say, both methods can not be compared. For example, even if the mean value of concentration apparently accords with each other, in the indirect method the reaction proceeds at the beginning in lower concentration, but gradually its concentration increases to the designated value at the end. As to temperature, too, only apparent temperature was determined, so the practical reaction temperature is higher in direct reaction, owing to exothermic reaction of producing C_2H_2 than in indirect reaction.

(C) In the case of 1% concentration at lower temperature the indirect might be preferable to the direct.

(3) Comparison of particle size for crystallite (ref. to Table 2).

By Seifert recording apparatus the particle size for crystallite was calculated from each diffraction line broading at diffraction angle 9.18° and 29.0° corresponding to diffraction planes (001) and (110).

(A) Direct reaction.

(a) Particle size for crystallite was maximum at 40% concentration.

(b) Thickness of plane (001) increased with temperature from 20°C to 80°C in lower concentration and it was constant in 40% concentration but decreased with temperature in 60%.

(c) However, thickness of plane (110) was constant in every concentration and temperature.

(d) Thickness of both planes (001) and (110) was about as twice as that in indirect reaction at same condition, except 60% concentration.

(e) Exception of 60% concentration would be illustrated by the fact that the production of C_2H_2 is retarded with increase of concentration, so that main reaction proceeds under equilibrium state whose reaction velocity increases with temperature.

(B) Indirect reaction.

(a) Thickness of plane (001) increased with temperature in lower concentration, but was constant in 40% and 60%.

(b) Thickness of plane (110) had no difference in every concentration.

(C) Mutual relation between filtration velocity and particle size.

(a) In such concentration of $MgCl_2$ as commercial bitter brine (from 20% to 40%), filtration velocity of product was corresponding to particle size.

(b) However in direct reaction of 60% concentration, filtration velocity increased against constant thickness of plane (110) in spite of increase of thickness of plane (001).

(c) In 1% concentration, filtration velocity of direct reaction was less than that of indirect reaction, but as to particle size it was on the contrary. This is attributed to the preparation of mixing various sizes of crystal, owing to the lack of uniform reaction in lower concentration.

(d) In higher concentration, the growing condition of crystal will be different because the manner of separation of $Mg(OH)_2$ from the surface of CaC_2 has influence upon concentration.

(4) Comparison of Ca content (ref. to Table 3).

Ca content in $Mg(OH)_2$ was compared at 20°C and expected results were obtained as follows.

(A) Ca content was lower at direct reaction than indirect.

(B) The difference was eminent in 1% concentration. This fact is illustrated by the conception that the formation of $CaCO_3$ with CO_2 in air was prevented, because in lower concentration the evolution of C_2H_2 is rapid, which prevents $Ca(OH)_2$ from contacting with CO_2.

3. Summary.

This manufacturing method of $Mg(OH)_2$ and C_2H_2 by direct reaction of CaC_2 with $MgCl_2$ solution, was named direct method. Another method on which C_2H_2 being produced from CaC_2 with H_2O, the residual milk of lime was added to $MgCl_2$ solution to obtain $Mg(OH)_2$ was named indirect method.

Both methods were compared with each other as to the filtration velocity of $Mg(OH)_2$, particle size of crystallite and its CaO content. In such a condition of 20% concentration of $MgCl_2$ at 20°C as in practical manufacture using bitter brine sea water which contained $MgCl_2$ from 20% to 40%, filtration velocity and particle size for crystallite of $Mg(OH)_2$ product were both better and its Ca content was less in direct reaction than in indirect.

Because, when CaC_2 reacts directly with $MgCl_2$ solution, evolution of C_2H_2 is retarded and the produced $Ca(OH)_2$ reacts with $MgCl_2$ at once so that free existence of $Ca(OH)_2$ is probably in very short time. Therefore the reaction proceeds as if CaC_2 is a weak alkali solution as NH_4OH. Besides under production of C_2H_2, CO_2 in air reacts with $Ca(OH)_2$ to get insoluble $CaCO_3$ which is residue in $Mg(OH)_2$ after washing. But from these experimental results so accurate conclusion could not be obtained in lower concentration (1%) and in higher concentration of 40%–60% as in 20% of concentration. The particle size for crystallite of $Mg(OH)_2$ increased with reaction temperature in 20% $MgCl_2$ solution. This fact would be illustrated by the decrease of solubility of $Ca(OH)_2$, which may be assured by determining pH of medium, in the next studies. Weak points of this method is exsistence of impurities. As to removal of impurities are to be done the studies on the water sieve of industrial product. The influence of size of CaC_2 is a important factor with respect to reaction apparatus and operation.

Table 1. Comparison of filtration properties

concentration (%)	temperature (°C)	velocity of filtration *(cc)	
		direct method	indirect method
1	20	3.3	9.5
1	40	6.5	9.9
1	60	12.7	12.3
1	80	16.6	14.4
20	20	13.7	12.2
20	40	16.7	13.5
20	60	17.8	13.3
20	80	20.0	13.5
40	20	17.0	15.0
40	40	19.0	16.9
40	60	19.5	15.7
40	80	20.1	17.2
60	20	15.0	14.7
60	40	18.7	15.9
60	60	20.5	16.9
60	80	20.6	17.5

* filtration amount for 10 min. out of 25 cc of solution.

Table 2. Comparison of crystallite size

concentration (%)	temperature (°C)	direct method (°A)		indirect method (°A)	
		(001)	(110)	(001)	(110)
1	20	85	202	40	113
1	40	75	202	43	123
1	60	85	202	70	113
1	80	140	208	75	113
20	20	133	270	58	123
20	40	150	246	68	123
20	60	170	246	68	123
20	80	240	270	75	135
40	20	240	270	93	123
40	40	240	270	100	135
40	60	240	300	100	135
40	80	265	270	110	150
60	20	240	270	125	150
60	40	185	270	110	135
60	60	120	270	110	123
80	80	133	270	120	150

Table 3. Comparison of CaO content in product

concentration %	CaO %	
	direct method	indirect method
1	0.38	1.14
20	0.55	0.98
40	0.56	0.95
60	0.60	0.95

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STUDIES ON THE DIRECT MANUFACTURE OF SODIUM HYDROXIDE AND OTHER MATERIALS FROM SEA WATER (Part V)

Influence of Co-existing Mg^{++} and Ca^{++} Ions on the Current Efficiency.

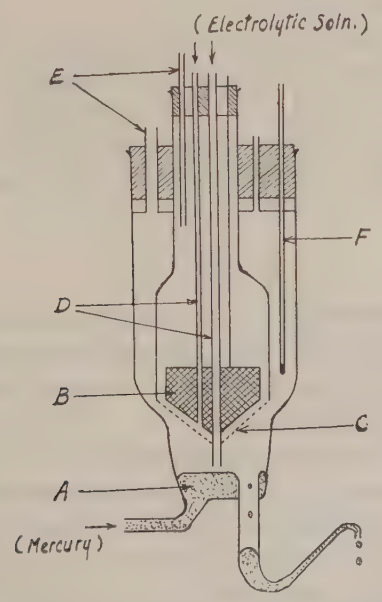
By
Taizo Kume and Takeo Hisano
(Faculty of Engineering, Tokushima University)

The influence of co-existence of Mg^{++} and Ca^{++} ions on the current efficiency of electrolysis of dilute NaCl-solution by a flowing mercury process has been studied in order to obtain NaOH. The results are summarized as follows.

Experimental

The electrolytic cell is, as shown in Fig. 1, a modified form of the Gösta Angel's apparatus,[1] fairly improved.

Fig. 1.



A: Cathode (mercury)
B: Anode (graphite)
C: Cellophane-membrane
D: Feed-pipe
E: Drain-pipe
F: Thermometer

1) J. Electrochem. Soc., 102, 124.

The solubility of chlorine in dilute NaCl-solution being much greater than in concentrated ones causes to drop the current efficiency of electrolysis almost to zero. To avoid this effect the cell is separated into anode and cathode chambers with a cellophane membrane and electrolytic solution is supplied into the chambers independently of one another.

The flow rate of the electrolytic solution in the cell is so controlled according to the current density as to consume about 1–2% of the NaCl in the solution.

The apparatus is devised to flow Na-amalgam formed by the electrolysis out of the cathode chamber and be deamalgamated; the current efficiency is determined by titrating the deamalgamated solution.

As the rate of supplying the mercury to the cathode has a marked influence on the current efficiency, a care was taken to keep the flow rate as constant as possible.

The NaCl is extra pure reagent and Mg^{++} and Ca^{++} ions are added in the form of the respective chloride.

Results and Consideration

Some of the experimental results are shown graphically in Fig. 2, 3, 4 and 5.

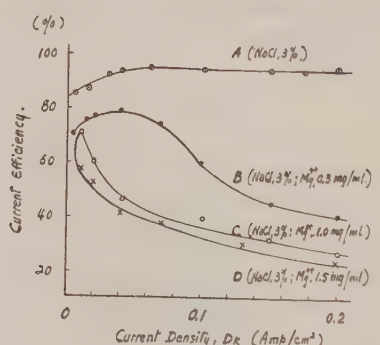


Fig. 2.

Fig. 2 shows the relation between current efficiency and current density. Curve A is for a solution of 3% of NaCl alone and shows that the current efficiency increases with the current density in its initial range, while the efficiency is hardly effected at the higher density.

Since the current efficiency is, as mentioned later, swayed by the flow rate of mercury of the electrode, i.e., by the amalgam concentration of the discharging surface and moreover the effect becomes remarkable when the Mg^{++} ions co-exist in the solution, the values represented in the figure are intrinsic, where the flow rate of mercury is about 10–13 c.c. per min.

Curves B, C and D are for 3% NaCl-solution with 0.3, 1.0 and 1.5 mg/ml Mg^{++} ions respectively. For small concentration of Mg^{++} ions, as in curve B or C, the current efficiency first rises with current density and then declines, pass-

ing through a maximum and the maximum occurs in the region where the curve A for pure NaCl-solution rises. The facts may be elucidated as follows; the increase of current density tends to increase the overvoltage of hydrogen, restraining the discharge of hydrogen ions, while it decreases the efficiency by the co-existent Mg^{++} ions in the solution. These two effects are considered to result the maximum in the curve.

When the concentration of Mg^{++} ions is increased near to that of sea water, as in curve D, the optimum efficiency disappears and the efficiency curve descends from the start with the increasing current density.

Fig. 3 shows how the Mg^{++} ions affect the current efficiency by a constant current density.

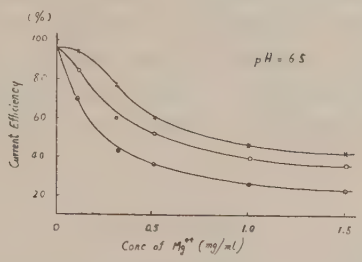


Fig. 3.

As seen from the figure, for the low concentration of Mg^{++} ions, the descending tendency of the efficiency curves is somewhat increased with growing current density. In the higher concentration, however, the curves have similar slopes with one another.

Fig. 4 is an example of NaCl-solution containing Ca^{++} ions for Mg^{++} ions and shows that Ca^{++} ions have not so noticeable effect as Mg^{++} ions.

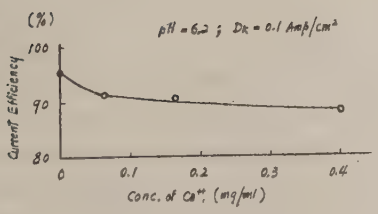


Fig. 4.

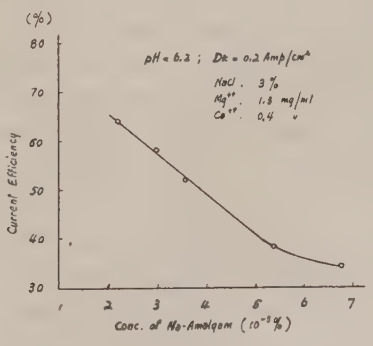


Fig. 5.

On the other hand, the flow rate of mercury has a remarkable effect on the efficiency, especially when the Mg^{++} ions co-exist in the solution. The concentra-

tion of Na-amalgam on the surface of mercury electrode can not be consistent with the analytical value of that in the mercury flowing out of the cathode chamber. Assuming, however, these two concentrations are the same, the current efficiency is plotted against the concentration of Na-amalgam as shown in Fig. 5. The curve is with regard to a solution similar in composition to sea water as for NaCl, Mg^{++} and Ca^{++} ions. As seen from the figure, the current efficiency decreases considerably with increasing concentration of Na-amalgam on the surface of cathode.

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PREPARATION OF POTASSIUM CHLORATE BY ELECTROLYTIC OXIDATION FROM BITTERN OR CARNALLITE

By
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(Himeji Technical College)

In this paper, experiments about separation of potassium chlorate which is produced by direct electrolytic oxidation of potassium salt contained in bittern or carnallite are reported. As for the research for the preparation of such chlorate by electrolysis of potassium salt or magnesium salt in bittern, method[1] of M. Ishibashi and Y. Harada and report[2] of M. Ishibashi and T. Harada have been known.

Experimentals

Sample: Chemical compositions of bittern and carnallite which are products of Akoo Nishihama Bittern Manufactory are given in Table I. As the electrolysis of carnallite was carried out in 35% aqueous solution, its chemical composition is also listed in Table I.

Apparatus for electrolysis: Using 12 Volt direct current as electric source and regulating electrolytic condition by rheostat with galvanometer and potentiometer, the concentration of potassium chlorate formed in the electrolytic solution was measured and current efficiencies during and after electrolysis were calculated. The electrolytic cell is a round vessel of glass (inside diameter—94 mm, height—135 mm). The anode is a round carbon-bar electrode (diameter—37 mm, length—180 mm) used for the manufacture of sodium hydroxide and the cathode is a porous cylindrical soft iron-plate having a slit of 2 mm width at the side of cylinder (its thickness—2 mm, diameter—72 mm, length—200 mm, diameter of perforation—8 mm, interval between perforations' centers—about 16 mm, number of perforations—6×11). An interval between anode and cathode is about 17 mm.

Analytical method: K^+ was determined by the gravimetric method that uses the reagent of sodium-cobalt nitrite. ClO_3^- was determined volumetrically by back titration with 0.1N—$KMnO_4$ after reduction with excess of 0.1N—Mohr's salt and addition of manganese sulfate. As ClO^- was not measured at all throughout the experiment, the content of $KClO_3$ was estimated from the data of ClO_3^- content determined by the above method, and the rate of $KClO_3$ production and electrical efficiency were calculated from the above.

Table I Chemical Composition of Sample

Sample	Baumé Degree °Bé	Temp. °C	Mg	K	SO_4	Cl
Bittern	28.0	28	6.262	1.908	4.267	19.556
Carnallite	···	···	7.841	11.256	1.372	37.765
35% Aq. Soln. of Carnallite	22.1	29	3.219	4.366	0.503	15.340

	$MgSO_4$	$MgCl_2$	KCl	NaCl	Total	Note
Bittern	5.347	20.291	3.638	4.479	33.755	g./100ml.
Carnallite	1.720	29.341	21.462	9.417	61.940	%
5% Aq. Soln. of Carnallite	0.630	12.107	8.320	3.905	24.962	g./100ml.

Results

Experiment No. 1—The electrolytic oxidation of KCl in bittern to $KClO_3$

Electrolytic solution: The sample used was 630 ml. of bittern, to which about 6 ml. of 6N-HCl was added for turning pH to 2.

Electrolytic condition: Electric current was 7.0Amp. and voltage was 2.7~2.8 Volt. The surface area of the anode of round-bar immersed in the electrolytic solution was 1.32 dm^2 and anodic current density was 5.30Amp./dm^2. The surface area of the cathode facing to anode immersed in the electrolytic solution was 2.26 dm^2 and cathodic current density was 3.10 Amp./dm^2. The temperature of the electrolytic solution was about 65°C by warming in air-bath.

Time of electrolysis: It was 17 hours. Quantity of electricity necessary for electrolytic oxidation of KCl in bittern to $KClO_3$ is calculated to be 49.04 Amp. hr. Therefore theoretical time of electrolysis calculated is 7 hours. During electrolysis the solution was not agitated and distilled water was added intermittently to fill up the loss of water by evaporation.

The results of measurement in electrolysis: Rates of formation of $KClO_3$ from KCl in bittern were determined by estimating $KClO_3$ in the solution several times during electrolysis. Current efficiencies were also calculated by using the following reactional equation of electrolytic oxidation as $KCl + 3H_2O \longrightarrow KClO_3 + 3H_2$. Therefore the quantity of electricity necessary for production of 1 mole of $KClO_3$ is 6 Faradays. The results of measurement are shown in Fig. 1.

Separation of $KClO_3$ from the electrolysed solution after conclusion of the reaction: Electrolytic deposition consisted mainly of $Mg(OH)_2$ was formed at the surface of cathode facing to anode and amounted to 99.5 g. which corresponded to 66.2 g. after air dried. This deposit contained electrically cor-

roded material of iron cathode in addition to $Mg(OH)_2$ as main component and water. 528 ml. of electrolysed solution (21.5°Bé at 23°C, pH 3.6) was filtered into a beaker and condensed by heating. When the temperature of the solution was raised to 111°C over 108°C at which crystals began to precipitate out, the heating was stopped and the solution was allowed to cool to room temperature 23°C. 104.6 g. of crude $KClO_3$ precipitated was filtered off by suction and 107 ml. of filtrate (31.8°Bé at 23°C) was obtained.

Chemical compositions of electrolysed solution, electrolytic deposition of cathode (analysis after air dried), crude $KClO_3$ and filtrate are listed in Table II. $KClO_3$ obtained in the above crude precipitate was 87.7% against total $KClO_3$

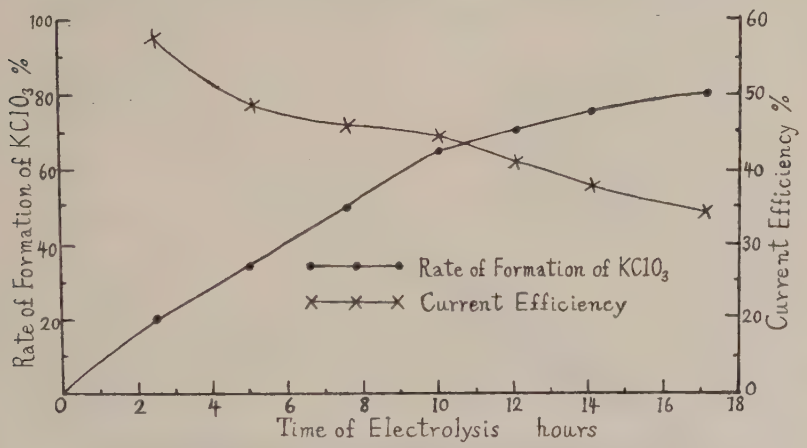

Fig. 1. Experiment No. 1. Rate of Formation of $KClO_3$ and Current Efficiency.

Table II Chemical Composition of Substance in Experiment No. 1

Substance	Mg	K	SO_4	Cl	ClO_3
Electrolysed Solution	7.682	1.825	4.329	8.227	3.461
Deposit of Cathode (Analysis after air dried)	31.613	2.446	1.654	4.245	1.017
Crude $KClO_3$	5.563	7.517	17.784	14.371	15.169
Filtrate	9.085	1.192	2.937	24.420	2.143

Substance	$MgSO_4$	$MgCl_2$	KCl	NaCl	$KClO_3$	$Mg(OH)_2$	Note
Electrolysed Solution	5.425	7.682	0.400	3.720	5.076	None	g./100ml.
Deposit of Cathode (Analysis after air dried)	2.073	...	...	...	...	74.803	%
Crude $KClO_3$	22.286	4.155	0.843	17.920	22.249	None	%
Filtrate	3.680	32.665	0.366	Trace	3.144	None	g./100ml.

produced in the electrolysed solution and also it was 61.6% against the theoretical amount of $KClO_3$ formed from KCl in the sample 630 ml. of bittern. 53.1% of Mg in bittern was deposited by electrolysis at the cathode mainly in the form of $Mg(OH)_2$.

Experiment No. 2—The electrolytic oxidation of KCl in carnallite to $KClO_3$.....(1)

Electrolytic solution: 640 ml. of 35% aqueous solution of carnallite was used. 1.92 g. of $K_2Cr_2O_7$ was added to the solution, which was made to pH 2 with 6N-HCl. For reference, the aqueous solution of this carnallite reaches the saturation point at about 45%.

Electrolytic condition: Electric current 7.0 Amp. Voltage 2.7~2.8 Volt. Anodic current density was 5.24 Amp./dm² and also cathodic current density

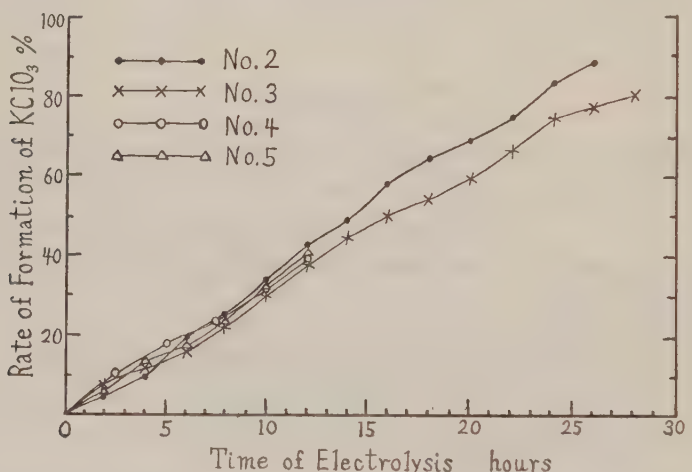

Fig. 2. Experiment No. 2~No. 5. Rate of Formation of $KClO_3$

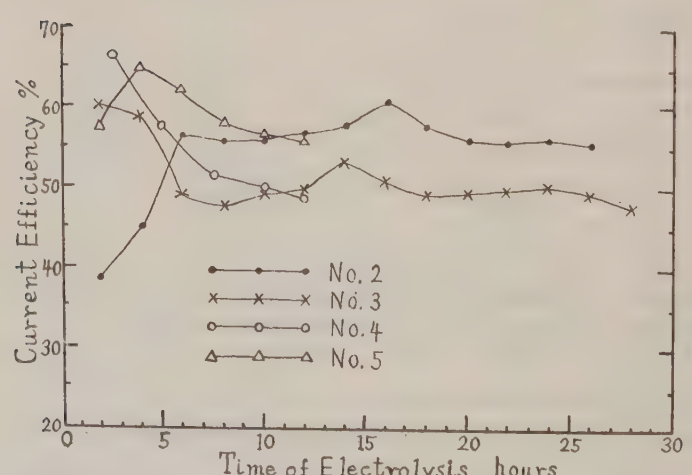

Fig. 3. Experiment No. 2~No. 5. Current Efficiency.

Table III Chemical Composition of Substance in Experiment No. 2

Substance	Mg	K	SO_4	Cl	ClO_3
Electrolysed Solution	···	···	···	···	9.015
Deposit of Cathode (Analysis after air dried)	25.859	3.881	1.646	3.347	4.325
$KClO_3$—(A)	Trace	···	···	0.638	53.105
$KClO_3$—(B)	0.216	···	···	1.262	67.226
Remaining Solution	2.581	3.342	1.705	14.680	4.967

Substance	$MgSO_4$	$MgCl_2$	KCl	NaCl	$KClO_3$	$Mg(OH)_2$	Note
Electrolysed Solution	···	···	···	···	13.222	None	g./100ml.
Deposit of Cathode (Analysis after air dried)	2.063	···	···	···	···	61.010	%
$KClO_3$—(A)	···	···	···	···	77.889	None	%
$KClO_3$—(B)	···	···	···	···	98.601	None	%
Remaining Solution	2.137	8.415	1.953	12.183	7.285	None	g./100ml.

was 3.08 Amp./dm². The electrolytic solution was not warmed during electrolysis and temperature of it was 28°C at the beginning and 42°C at the ending.

Time of electrolysis: It was 26 hours, but the theoretical time calculated is 16 hours and 25 minutes.

The results of measurement in electrolysis: These are shown in Fig. 2 and Fig. 3.

Separation of $KClO_3$ from the electrolysed solution: After conclusion of electrolysis, 581 ml. of the solution (16.7°Bé at 42°C) was allowed to cool to room temperature 28°C and 19.72 g. of $KClO_3$—(A) was precipitated and 574 ml. of filtrate (15.1°Bé at 23°C) was obtained. 574 ml. of filtrate was concentrated by heating and the heating was interrupted at the time when crystallization began upon the surface of a liquid. After cooling to room temperature and filtration, 41.50 g. of $KClO_3$—(B) deposit and 172 ml. of the remaining solution (27.0° Bé at 29°C, pH 4.4) were obtained.

Electrolytic deposition was also found in the inner surface of the cathode in the electrolysis of carnallite as in the case of bittern. The amount of the deposit was 75.4 g. which corresponded to 61.0 g. after air dried. These chemical compositions are listed in Table III. The slightly low content of $KClO_3$—(A) was due to the admixture of corroded matter of electrode. The yield of $KClO_3$ obtained in the above $KClO_3$—(A) and $KClO_3$—(B) was 72.2% against total $KClO_3$ poduced in the electrolysed solution. $KClO_3$ content in $KClO_3$—(B) gained after condensation and cooling was as high as 98.60% (cf. Table III). When condensation of the filtrate after separation of $KClO_3$—(A) was proceed-

ed a little further than the state at which crystals began to separate out upon the surface of the solution as the case in this experiment, the yield of K in the form of $KClO_3$ could be increased. 76.5% of Mg in carnallite was deposited by electrolysis at the cathode mainly in the form of $Mg(OH)_2$.

Experiment No. 3—The electrolytic oxidation of KCl in carnallite to $KClO_3$.....(2)

The electrolytic solution and the electrolytic condition were the same as those in experiment No. 2, but $K_2Cr_2O_7$ was not added in this experiment. The electrolytic solution was not warmed and the temperature during electrolysis was 28~42°C as before. The time of electrolysis was 28 hours. The results of measurement are also shown in Fig. 2 and Fig. 3.

Experiment No. 4—The electrolytic oxidation of KCl in carnallite to $KClO_3$.....(3)

In this experiment, Ni electroplated electrode (its material and shape were the same as the former experiment), which has low hydrogen overvoltage, low electrolytic reduction at the cathode and comparatively better resistance for corrosion, was used as the cathode in order to decrease the electrolytic deposit of $Mg(OH)_2$ at the cathode.

The electrolytic solution used was the same as one in experiment No. 3 and $K_2Cr_2O_7$ was not also added. The electrolytic condition was the same as before, but the voltage was slightly high 2.8~2.9 Volt. The temperature during electrolysis was 28~35°C and the time of electrolysis was 12 hours.

The results of measurement are also shown in Fig. 2 and Fig. 3. The amount of deposit on the Ni plated cathode was 15.0 g. after air dried and the content of $Mg(OH)_2$ in the deposit was 61.20%. Therefore, 18.6% of Mg in carnallite was deposited at the cathode mainly in the form of $Mg(OH)_2$.

As the iron electrode used for the preparation of Ni plated electrode was later found out that corrosion had advanced into the body and Ni was not electroplated satisfactorily, it may be presumed that better results could be obtained with a better Ni covered electrode.

Experiment No. 5—The electrolytic oxidation of KCl to $KClO_3$

This experiment was undertaken as a contrast and 640 ml. of 24% aqueous solution of KCl was used for electrolysis. 1.92 g. of $K_2Cr_2O_7$ was added to the KCl solution, which was made to pH 2 with 6N-NCl. Electric current 7.0 Amp., voltage 2.6~2.75 Volt, temperature 28~37°C and time of electrolysis was 12 hours. Electrodes were the same as those in experiment No. 1~No. 3.

The results of measurement are also shown in Fig. 2 and Fig. 3.

Discussions

(1) In electrolytic oxidation of KCl in bittern to $KClO_3$, it is suitable to take the time of electrolysis between 1.4~1.7 times the caluculated one. Therefore, it is 10~12 hours in the case of experiment No. 1. In this condition, the rate of formation of $KClO_3$ in the electrolysed solution is 65~70% against

the theoretical amount of $KClO_3$ formed from KCl in bittern, and the current efficiency is 45~42% (cf. Fig. 1).

In the experiment No. 1, about 53% of Mg in bittern was deposited at the cathode mainly in the form of $Mg(OH)_2$. Crude $KClO_3$ obtained from the electrolysed solution has low purity and is contaminated with a large amount of $MgSO_4$ and NaCl (cf, Table II). Even when the maximum temperature in condensation was lowered to 107°C at which crystals began to separate out, it showed no other improvement than to increase slightly the purity of the crude $KClO_3$. (The experiment is omitted.)

(2) In electrolytic oxidation of KCl in carnallite to $KClO_3$, it is advisable to electrolyse considerably longer than the time required by calculation.

Times of electrolysis in experiments No. 2 and No. 3 are each 1.6 times and 1.7 times calculative those. Rates of formation of $KClO_3$ are each 90% and 80% and current efficiencies are 56% and 47% (cf. Fig. 2 and Fig. 3). When it adequately prolonged the time of electrolysis, the rate of formation of $KClO_3$ was increased, but the current efficiency was slightly inferior.

Addition of a small quantity of $K_2Cr_2O_7$ seems to be effective (cf. Experiment No. 2 and No. 3, Fig. 2 and Fig. 3). When current efficiency in the electrolytic oxidation of the aqueous solution of carnallite is compared with that of KCl, it is found that the former is slightly inferior at the beginning of electrolysis but almost the same later throughout the reaction (cf. Experiment No. 2 and No. 5, Fig. 3).

In the electrolysis of the aqueous solution of carnallite, a large amount of $Mg(OH)_2$ is deposited at the cathode, when iron plate is used as a cathode and the solution is not agitated (cf. Experiment No. 2). To decrease the amount of this deposit and to prevent the corrosion of cathode by electrolysis, it is preferable to use Ni plated electrode (cf. Experiment No. 4), stainless steel or Ni—Cr electrode. In all the experiments given in this paper, the solution for electrolysis was not agitated and the electrode of the same shape was used and the cathodic current density was about 3.1 Amp./dm^2. But, if the solution is agitated or streamed during electrolysis and the cathodic current density is risen to about 4 Amp./dm^2, better results in current efficiency and others may be expected.

Consumption of the carbon anode was a little, but it was especially conspicuous in the final stage. It will be safe to use magnetite electrode if necessary.

Acknowledgment

The author expresses his sincere thanks to Professor M. Ishibashi for his kind guidance and encouragement throughout this study.

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1) M. Ishibashi and Y. Harada, Japanese Patent 137,859, (1940)
2) M. Ishibashi and T. Harada, Bulletin of the Society of Salt Science, Japan, Vol. 7, 215, (1953); Vol. 8, 75, (1954); Vol. 8, 130, (1954)

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October 1959

ON THE NATURAL RADIOACTIVITY OF THE MARINE SEDIMENTS

(Part I. Preliminary Report)

By
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(Tokyo University of Fisheries)

It is an important problem that how is the rate of the pollution by the dust of artificial radioactive materials which were dumped in the sea. The research of the radioactivity of the sediment is one of the good ideas for the solution of the problem, but it is necessary to take the natural radioactivity into account.

It seems that there is a caudal dependence on the distribution of radioactivity of the marine sediment and the radioactive mineral ores which distributed along the coast. There is a good example at the central region in Seto-Naikai i.e. the Inland Sea of Japan. Onsengun, Ehime Prefecture belongs to the granite region on the view point of geology, and there develop many pegmatite veins through granite. Pegmatite veine contains many kinds of radioactive minerals as monazite.

Shiroiwa, Fujigasaki, Nakagawa, Tateiwa, Komenono and Sarukawa at Onsengun, Ehime Prefecture are known as regions where the natural radioactivity is very strong.

In 27th and 28th of November, 1957, Shinyomaru, research vessel of the Tokyo University of Fisheries surveyed the bottom of the sea off the coast of Onsengun, Ehime Prefecture from Daikaku-Hana to Kashima along Kurushima Strait and obtained the bottom materials from 12 stations.

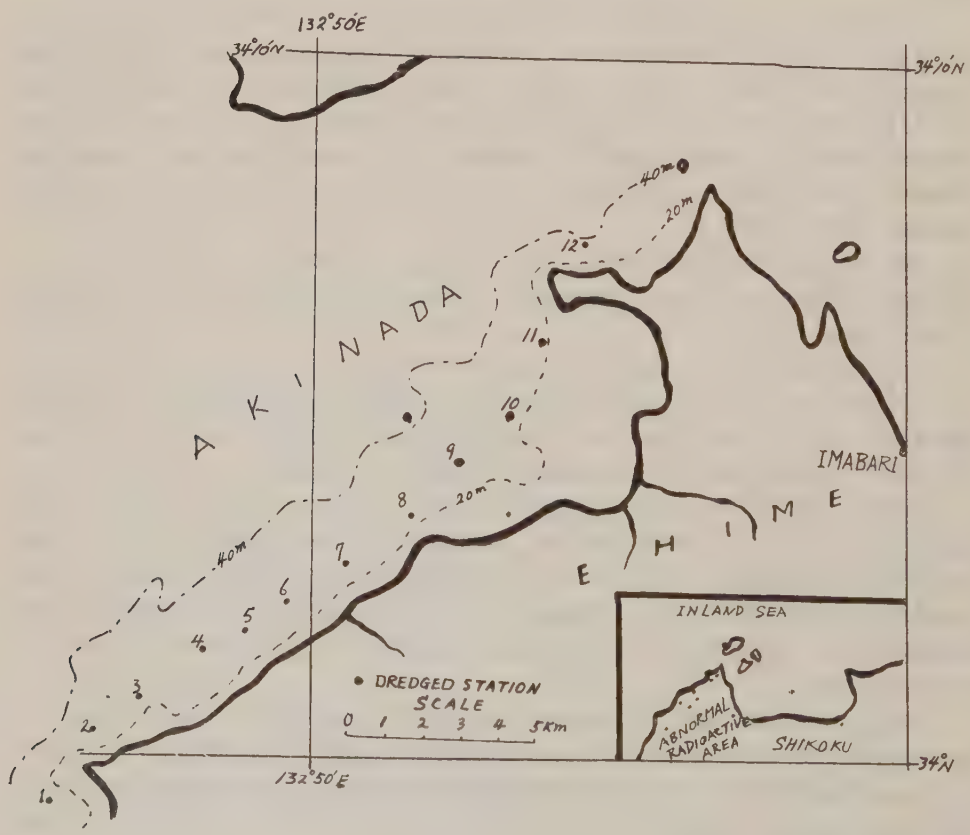
The bottom materials from those stations consist of gravel, coarse sand, fine sand, mud and organic remains. Judging from the character of the rock and mineral, inorganic materials were originated in granite or pegmatite. The natural radioactivity is very strong in the bottom materials obtained from stations 1, 3, 5, 8 and 11. The study on the kind of the radioactive minerals is now going on.

The tidal current of Kurushima Strait is very strong, at some times, it reaches more than five nautical miles per hour. Such a condition is very good for the accumulation of the heavy radioactive minerals by the natural selection from the weathered materials of granite or pegmatite which were derived from the coastal region.

Table I. Dredged stations at the coast of Ehime Prefecture

Station Number	North Latitude	East Longitude	Depth	Bottom Character
St. 1	33 59.3N	132 45.7E	18 m.	Gravel. Coarse sand
St. 2	34 00.3	132 46.5	23	Coarse sand
St. 3	34 00.8	132 47.2	45	Coarse sand
St. 4	34 01.5	132 48.2	36	Fine sand
St. 5	34 01.9	132 49.0	34	Coarse sand Mud
St. 6	34 02.3	132 49.7	25	Fine sand
St. 7	34 02.9	132 50.7	25	Coarse sand Gravel
St. 8	34 03.5	132 51.8	24	Gravel Coarse sand
St. 9	34 04.4	132 52.6	32	Fine sand
St. 10	34 05.0	132 53.5	22	Fine sand
St. 11	34 06.0	132 53.8	40	Fine sand
St. 12	34 07.5	132 54.8	22	Fine sand

The map showing the dredged stations.



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COASTAL GEOLOGY OF THE KII PENINSULA

By
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Field observations were made along the southern tip to the eastern parts of the Kii Peninsula during 1957, with the purpose to study marine erosion and evidence for recent changes in sea-level because this has intimate relation with the finding of cultural grounds for shell-fish. Also an attempt was made to determine the relation between erosion and deposition of gravels by marine agencies because the problem is important in development of cultural grounds and also in geology.

As a result of the studies, the writer found that several types of marine pot-holes of similar shapes are due to different processes of erosion. The preliminary report has been published under the title "A Note on the Development of Certain Marine Pot-holes along the West Coast of Wakayama Prefecture, Japan", and, "An Erosion Feature Observed in Wakayama and Shizuoka Prefectures".

Recent changes of sea-level as observed in the Kii Peninsula and in the Izu Peninsula, have been published under "Observations along the Southern Coast of Izu Peninsula, Shizuoka Prefecture", and, "Preliminary Observations along the Sea Coast of Wakayama Prefecture, Japan". In the two reports it was shown that areas subjected to emergence and active erosion are unsuitable for fish culture, and evidence was given. Also, raised sea-notches along the eastern coast of the Atsumi Peninsula, Aichi Prefecture, raised beach deposits and benches along the west coast of Wakayama Prefecture, and the development of young marine terraces along the coast of Mie Prefecture, all provide evidence for recent uplift of those regions. A part of the work has already appeared under the title of "Evidence of an Ancient Shoreline on a Marine Terrace, West Coast of Wakayama Prefecture, Japan", and reports concerning other evidence are being prepared.

Presently the problem of marine erosion and the development and deposition of its products is being studied. Active weathering along joints and fissures or cracks developed in massive rocks as quartz-porphyry results in the prying off of large blocks, which fall immediately into the adjacent sea. However, after their fall into the sea they are transported by currents and waves by which action they are transformed into boulders and later to cobbles. These same agencies determine their final place of deposition and orientation, and the

former, in the case studied, is not the sea area immediately below the sea-cliff from where they were derived.

Also, especially along the southeastern coast of Kii Peninsula in Mie Prefecture where the Mesozoic thin alternations of sandstone and siltstone with interbedded sandstones are inclined at various angles being sometimes overturned and exhibit remarkable examples of penecontemporaneous secondary deposition, studies were undertaken concerning erosion, weathering and deposition of their products. Also the various structures preserved in the homogeneous massive sandstones were also observed. This study is now being continued and the results will be published after completion of the work.

Studies on the notches developed along the coasts of the Kii Peninsula and of the Atsumi Peninsula were made with regard to their shape, position and relation with the strand-line, kind of rocks in which they are incised, relation of them to wave and current direction, and of the characteristics of the sea-level and raised notches. Since the study has not been sufficient, further observations are expected to be undertaken during 1958. It is hoped that the notches observed in the said area compared with those developed in more northern regions, will turn out to build a classification of them favorable for a working tool in marine geology.

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GROWTH OF SULPHATE-REDUCING BACTERIA IN RELATION TO THE OXIDATION-REDUCTION POTENTIAL OF CULTURE MEDIA

By
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Hideo Miyoshi*
(Faculty of Agriculture, Kyoto University)

In the water-world of nature, in general, physical and chemical conditions of environments are the important factors which decide the conduct to be select in the kinds of growing organism, and also these conditions must be altered to various degrees by the property and the power of biochemical activities of organisms especially microorganisms existed.

The living conditions of all organisms under water such as aquatic plants and animals are remarkably influencend by the growth of sulphate-reducing bacteria which produce a large amount of hydrogen sulphide. Because the changes of physical and chemical conditions occur in the environments by the hydrogen sulphide produced. Also it is clear that the growth and the activity of sulphate-reducing bacteria are influenced by the environmental condition.

Sulphate-reducing bacteria are belonging to obligate anaerobes and can grow in the media having low oxidation-reduction potential alone. Therefore, in the water-world of nature, in general, the production of hydrogen sulphide by these bacteria takes place in the bottom mud which is supplied in little amount of oxygen. Under such conditions, when hydrogen sulphide is produced, the oxidation-reduction potential of the environments becomes lower with the increase of its amount and moreover such environments are outspread to wider spheres, and then the vital function of all organisms which must respire oxygen is perfectly obstructed.

From the point of view of production of available plants and animals, therefore, it is considered to be of importance that the study on the relation between the growth of sulphate-reducing bacteria and the oxidation-reduction potential of media is carried out. Although a few papers concerning this problem have been published up to date, it does not appear that these papers accord in the results obtained. ALESHINA (1938)[1] found that the reduction of sulphide takes place at *Eh* +27 mV and the oxidation-reduction potential is lowered to

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Eh −200 mV∼−300 mV with the progress of the reduction. STARKEY and WIGHT (1945)[2] reported that sulphate-reducing bacteria grow at *Eh* +300 mV between pH 5.5∼8.5 and the *Eh* value lowers to −200 mV∼−300 mV with the bacterial growth. According to ZoBELL and RITTENBERG (1948)[3] sulphate-reducing bacteria grow well between *Eh* −100 mV∼−300 mV at a temperature of 30°C in the case of pH 7. By BAAS-BECKING and WOOD (1955)[4] it has been reported that the growth of these bacteria occurs between *Eh* +110 mV∼−400 mV.

The present paper deals with the experiments carried out to ascertain the upper limit of oxidation-reduction potential which permits the growth of sulphate-reducing bacteria and the change of *Eh* value occurring in media during the growth of these bacteria.

Experiments

1. Development of sulphate-reducing bacteria in the media containing L-ascorbic acid in various concentrations.

In this experiment, the effect of oxidation-reduction potential upon the development of sulphate-reducing bacteria is studied, using the media containing L-ascorbic acid in various concentrations.

Medium employed: As the basal medium, Medium I[5] which has been used for the cultivation of sulphate-reducing bacteria by the present authors

Medium I

Ca-lactate	3.5 g
Beef extract	1.0 g
Peptone	2.0 g
KH_2PO_4	0.2 g
$MgSO_4 \cdot 7H_2O$	0.2 g
$FeSO_4 \cdot 7H_2O$	0.2 g
Agar	3.0 g
Filtered sea water	1 L
pH	7.5

is employed. Then the definite amount of L-ascorbic acid (0, 0.01, 0.02, 0.03, 0.05, 0.10, 1.00 g/L) is added to this medium aseptically.

Procedure: The sulphate-reducing bacteria SM_1, the similar kind of *Desulfovibrio aestuarii*, isolated from marine bottom mud is inoculated into Medium I containing 0.1 g/L of L-ascorbic acid but no agar, and harvested aseptically after 36 hours at 30°C. After the bacterial cells have been washed with 3 % sterilized salt solution, heavy cell suspension is made. This suspension is introduced into the above mentioned media. There are $10^2 \sim 10^3$ cells per 1 ml of the media inoculated. At a temperature of 30°C is the incubation done of the whole cultures inoculated. A definite volume of the cultures is taken out after those have been allowed to stand for definite intervals, and counts of the bacterial cells are made by the extinction dilution method.

Table 1. Growth of sulphate-reducing bacteria in the media containing L-ascorbic acid in various concentrations.

Conc. of L-ascorbic acid in the medium (g/L)		Incubation time (hrs)									
		0	12	20	31.5	41	55.5	68	79	97	121
0	Cells/ml	10^2—10^3	10^2—10^3	10—10^2	10—10^2	1—10	1—10	0	0	0	0
	H_2S (mg/ml)	0	0	0	0	0	0	0	0	0	0
	Eh (mV)	338.7	337.9	339.6	329.4	323.8	324.4	322.4	324.6	326.4	326.0
0.01	Cells/ml	10^2—10^3	10^2—10^3	10^4—10^5	10^4—10^5	10^7—10^8	10^7—10^8	10^8—10^9	10^9—10^{10}	10^9—10^{10}	10^9—10^{10}
	H_2S (mg/ml)	0	0	0	0	0.004	0.011	0.126	0.260	0.228	0.224
	Eh (mV)	188.0	207.7	217.8	207.0	−25.2	−43.9	−153.3	−157.5	−165.9	−154.4
0.02	Cells/ml	10^2—10^3	10^2—10^3	10^5—10^6	10^5—10^6	10^7—10^8	10^7—10^8	10^8—10^9	10^9—10^{10}	10^9—10^{10}	10^9—10^{10}
	H_2S (mg/ml)	0	0	0	0	0	0.014	0.185	0.314	0.317	0.273
	Eh (mV)	153.8	153.5	153.6	4.4	−83.9	−71.6	−147.8	−161.6	−145.8	−163.4
0.03	Cells/ml	10^2—10^3	10^3—10^4	10^6—10^7	10^6—10^7	10^7—10^8	10^7—10^8	10^8—10^9	10^9—10^{10}	10^9—10^{10}	10^8—10^9
	H_2S (mg/ml)	0	0	0	0	0	0.029	0.294	0.320	0.310	0.235
	Eh (mV)	141.9	143.5	145.7	7.9	−98.3	−96.8	−154.4	−159.6	−164.0	−143.9
0.05	Cells/ml	10^2—10^3	10^3—10^4	10^6—10^7	10^7—10^8	10^7—10^8	10^7—10^8	10^9—10^{10}	10^9—10^{10}	10^9—10^{10}	10^8—10^9
	H_2S (mg/ml)	0	0	0	0	0.019	0.033	0.294	0.334	0.281	0.307
	Eh (mV)	135.0	132.8	119.1	−4.6	−102.1	−110.0	−158.8	−160.5	−146.6	−148.2
0.10	Cells/ml	10^2—10^3	10^3—10^4	10^6—10^7	10^7—10^8	10^7—10^8	10^8—10^9	10^9—10^{10}	10^9—10^{10}	10^9—10^{10}	10^9—10^{10}
	H_2S (mg/ml)	0	0	0	0	0.023	0.043	0.304	0.320	0.288	0.285
	Eh (mV)	106.7	97.4	80.4	5.5	−94.1	−99.8	−143.7	−142.8	−153.8	−143.5
1.00	Cells/ml	10^2—10^3	10^3—10^4	10^6—10^7	10^7—10^8	10^7—10^8	10^8—10^9	10^9—10^{10}	10^9—10^{10}	10^9—10^{10}	10^9—10^{10}
	H_2S (mg/ml)	0	0	0	0.011	0.201	0.363	0.269	0.304	0.290	0.242
	Eh (mV)	57.4	35.6	17.2	−80.1	−131.8	−154.5	−162.6	−148.6	−146.2	−145.1

At the same time the *Eh* of the culture media and the amount of hydrogen sulphide are also determined.

Results: Results obtained are as shown in Table 1.

The sulphate-reducing bacteria can grow and hydrogen sulphide can develop in the media containing L–ascorbic acid, but not in the media containing no L–ascorbic acid. That is to say, the bacterial growth takes place when the *Eh* is lower than +188 mV, although it is slightly retarded when the *Eh* is higher than +144 mV.

The change of *Eh* occurring in the media and the production of hydrogen sulphide are corresponded with the rate of the bacterial growth. In all cases, the lowest value of *Eh* during the growth period is about −160 mV.

2. Development of sulphate-reducing bacteria existing together with a certain kind of aerobic bacteria.

It is expected that when sulphate-reducing bacteria is mixed with a certain kind of aerobic bacteria, it can develop in the media containing no reducing substances. Because, oxygen present in the media may be consumed by the latter and the potential may be lowered to a suitable level for the growth of the former.

This experiment is undertaken to ascertain such problem as aforementioned.

Procedure: The same procedure which has been used in the Experiment 1 is used in this experiment, excepting the aerobic bacteria employed.

Aerobic bacteria employed are two strains (V_2 and C_1) of the pure cultures isolated from the crude culture of the sulphate-reducing bacteria SM_1. The definite amount of these bacterial cells (1−10 or $10 \sim 10^2$ per ml of the media)

Table 2. Growth of sulphate-reducing bacteria exisiting together with other aerobic bacteria.

Conc. of L-ascorbic acid in the medium (g/L)	Cultures		Incubation time (hrs)			
			0	25	42	68
0	pure	Cells/ml	$10–10^2$	$10–10^2$	$10–10^2$	1–10
		H_2S (mg/ml)	0	0	0.007	0
		Eh (mV)	317.5	319.9	320.8	319.2
0.12	pure	Cells/ml	$10–10^2$	$10^7–10^8$	$10^8–10^9$	$10^9–10^{10}$
		H_2S (mg/ml)	0	0	0.346	0.151
		Eh (mV)	107.4	−131.5	−145.7	−128.9
0	mixed with V_2	Cells/ml SM_1	$10–10^2$	$10^2–10^3$	$10^7–10^8$	$10^9–10^{10}$
		Cells/ml V_2	1–10	$10^7–10^8$	$10^8–10^9$	$10^8–10^9$
		H_2S (mg/ml)	0	0	0.018	0.263
		Eh (mV)	315.4	167.2	−17.1	−158.4
0	mixed with C_1	Cells/ml SM_1	$10–10^2$	$10^4–10^5$	$10^8–10^9$	$10^8–10^9$
		Cells/ml C_1	$10–10^2$	$10^7–10^8$	$10^8–10^9$	$10^8–10^9$
		H_2S (mg/ml)	0	0	0.043	0.314
		Eh (mV)	316.9	155.0	−40.4	−164.5

is added to the media at the same time when the sulphate-reducing bacteria is inoculated.

Results: Results obtained are given in Table 2.

In the pure culture of the sulphate-reducing bacteria, the same results which has been obtained in the Experiment 1, are shown as for the growth. However, in the mixed cultures with aerobic bacteria, the sulphate-reducing bacteria can grow in the media containing no L-ascorbic acid. In this case, although in the early stage of the development the rate of growth is slightly smaller than that in the case of the media containing 0.12 g/L of L-ascorbic acid, the rate is rapidly larger when the *Eh* becomes lower than a certain degree by the growth of aerobic bacteria.

As for the lowest value of *Eh* during the growth period and the amount of hydrogen sulphide produced, the same results which are obtained in the case of the media containing L-ascorbic acid, are given.

3. Growth of aerobic bacteria in relation to the oxidation-reduction potential of media.

This experiment aims to ascertain the change of *Eh* value occurring in media during the growth of the aerobic bacteria which were used in the Experiment 2.

Procedure: The same procedure as above described is used. But the medium employed does not contain L-asorbic acid and Medium I is used as it is.

Results: As shown in Fig. 1, in all cases, the *Eh* becomes rapidly lower with the bacterial growth and it is lower than −100 mV after 12 hours.

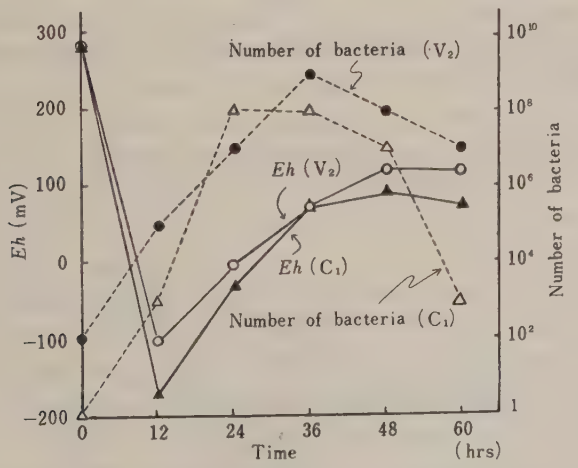

Fig. 1. Change of oxidation-reduction potential occurring in media during the growth of aerobic bacteria.

From the above mentioned, the fact that the sulphate-reducing bacteria can develop in the media containing no reducing substances when it is existing together with other aerobic bacteria, is clear to be due to the lowering of *Eh* based on the growth of aerobic bacteria.

4. Effect of aeration on the growth of sulphate-reducing bacteria.

This experiment aims to elucidate how the effect has upon the growth of sulphate-reducing bacteria and the production of hydrogen sulphide when the *Eh* of media is raised by means of aeration, after the bacterial growth has taken place in the media containing L–ascorbic acid.

Procedure: The sulphate-reducing bacteria SM_1 is cultured in the Medium I containing 0.1 g/L of L–ascorbic acid by the same method as above described. After standing for about 30 hours, the culture is aerated for 30 hours under an aseptic condition and then incubated again as it is. The experiment is performed

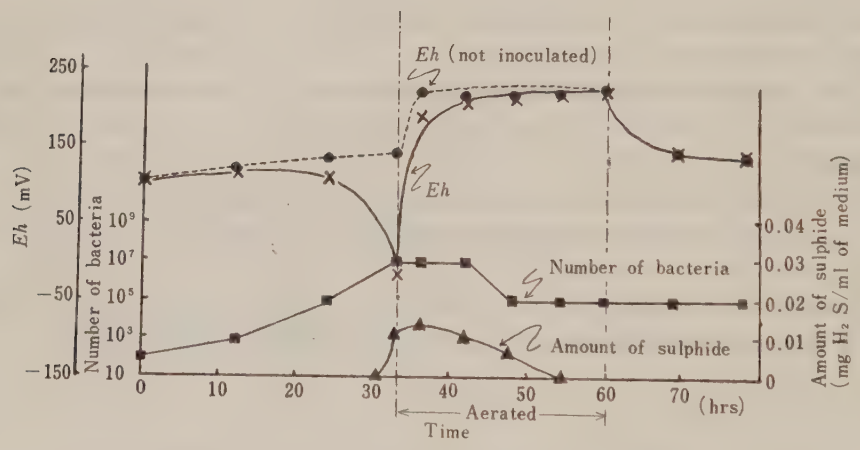

Fig. 2-a. Effect of aeration on the growth of sulphate-reducing bacteria.

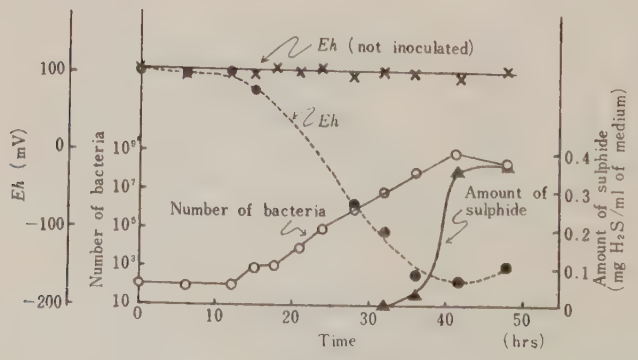

Fig. 2-b. Change of oxidation-reduction potential occurring in media during the growth of sulphate-reducing bacteria.

in duplicate, including a control which is not aerated. The surface of the madia is covered with liquid paraffin in the control.

Results: Results obtained is illustrated graphically in Fig. 2.

The *Eh* of media rapidly lowers when the growth has approached to the logarithmic phase. During this phase, if the aeration is performed, the *Eh* is rapidly raised and becomes higher than +200 mV by the aeration for several hours. This value is extraordinarily higher than that of the initial *Eh* of media. In this value, it is clear that the sulphate-reducing bacteria can not grow and consequently hydrogen sulphide is not produced. After the aeration has been forbidden, the *Eh* of media gradually lowers and reaches to the equilibrium near the initial value. Even under such a condition, the bacteria can not grow again. By the aeration, it is certainly understood that the increase of hydrogen sulphide ceases and the decrease begins gradually.

Discussion

From the Experiments 1, 2 and 3, it is evident that in the case of pure culture, the sulphate-reducing bacteria can develop in low-potential-media containing some reducing substances but not in high-potential-media, and that in the case of mixed culture with other aerobic bacteria, it can develop even in high-potential-media. It is considered, consequently, that in the natural world a suitable condition for the growth of sulphate-reducing bacteria may be made even under an aerobic condition.

As shown in the Experiment 4, when the sulphate-reducing bacteria is aerated during the logarithmic growth phase, the *Eh* of media is rapidly raised, and the bacterial growth and the production of hydrogen sulphide cease. Also the bacterial growth does not take place even after the *Eh* has been lowered again by the forbidding of aeration. As for this phenomenon, it is presumed that the inhibition of the bacterial growth has been brought about by something of unknown factors excepting the potential. Because the *Eh* at this time is the value which permits to develop the bacteria as shown in the Experiment 1. As the inhibiting factor, however, the potential may have to be considered from the fact that the lag phase of growth is retarded when the potential is considerably high even if the growth takes place. Because, in the Experiment 4, after the aeration has been forbidden the incubating time is considerably short, namely, 20 hours.

According to STOLP (1955)[6] when *Clostridium butyricum* is aerated during the logarithmic growth phase, its growth ceases, and then it rapidly grow again to the logarithmic growth phase after the aeration has been forbidden. Our observation is varied from his, that may be due to differences of organism employed, etc. The details of this problem are beyond our comprehension, and more researches are necessary for the solution of the problem.

From the above mentioned, it is suggested that a fishing ground (especially shallow sea) which has been ruined by the production of sulphide may be

recovered again, since the growth of sulphate-reducing bacteria may be inhibited, if the aeration is performed to the bottom mud by means of the ploughing.

Summary

1. The growth of the marine sulphate-reducing bacteria takes place when the *Eh* of media is lower than +188 mV, although its growth is retarded when the *Eh* is higher than +144 mV.

2. In the mixed culture with a certain kind of aerobic bacteria, as the potential of media is lowered by the aerobic one, the marine sulphate-reducing bacteria can develop in the media containing no reducing substances such as L-ascorbic acid.

3. When the culture of the marine sulphate-reducing bacteria is aerated during the logarithmic growth phase, the potential of media is rapidly raised and the bacterial growth ceases, and then the bacteria can not grow even after the aeration has been forbidden.

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TWO NEW TYPES OF LUMINOUS FISH ORGAN, NOTES ON BIOCHEMICAL RESEARCH CONDUCTED, AND A CLEAR DEMONSTRATION OF LUCIFERIN LUCIFERASE REACTION THEREIN*

By

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The following report illustrates some of the results obtained from studies made during 1957 and 1958 in the waters adjacent to the Pacific coasts of Japan through the aid of the Committee on Marine Resources of the Japanese National Commission for Unesco.

Most known luminous fish of the suborder Stomiatina and the order Myctophida are found in deep oceanic waters and have on the surface of their heads or bodies or on their barbels, curious arrangements of luminous organs of varied shapes, sizes and arrangements. These organs are of the direct emission type. That is, their luminescence is emitted directly from the luminous body.

Some luminous fish show no outward peculiarities in appearance and resemble ordinary non-luminous fish. This is because the luminous body lies inside the fish and cannot be seen. The light is reflected to pass through a translucent area of muscles where it appears as a diffused bluish glow. This diffusion may be compared with the effect which a opal bulb of an electric lamp has in screening the glare of the incandescent filament and reducing it to a diffused glow. As far as is known, this indirect emission type is confined to Acropomidae, Leiognathidae, *Paratrachichthys prosthemius*, *Apogon ellioti* and *Siphamia versicolor* (IWAI, 1958).

The present study concerns other luminous organs of the same type, which were detected by the author in *Parapriacanthus beryciformes* FRANZ of the family Pempheridae, and also biochemical research on the luminous substance of this fish and *Apogon ellioti*, which was carried out as a collaborative work with Dr. Frank H. JOHNSON of Princeton University.

Parapriacanthus beryciformes is originally described and classified by FRANZ in 1910 on the basis of preserved specimens obtained near Yokohama from the collections of HABERER and DOFLEIN. Understandably, the original descrip-

* Aided by the Committee on the Research of Marine Resources sponsored by the Japanese National Commission for Unesco and Princeton University.

tion neither mentions luminescence as a characteristic nor refers to the hidden luminous organs, inasmuch as the luminescence is revealed only through careful observation of fresh materials in the dark.

The luminous organs consist of two ducts underlying translucent muscle tissue on the ventral side between the pectoral fin and anus. The morphology of the luminous organ of this fish was given in "Records of Oceanographic Works in Japan" (Special number 2, March 1958) while the results of biochemical research on the luminous materials of this fish were given in "the Proceedings of the National Academy of Science" (Vol. 44, No. 2, February 1958) and in "the Science Report of the Yokosuka City Museum" (No. 3, March 1958) as a collaborative work with Dr. Frank H. JOHNSON of Princeton University.

Hot water extract (heat stable, Luciferin) prepared from the luminous duct of this fish by boiling and grinding, respectively, did react luminescently with cold water extract (heat labil, Luciferase) from the luminous duct. Extracts prepared separately from the thoracic and anal ducts cross-reacted to produce light, but no luminescent cross reaction occurred between these extracts and prepared from non-luminous tissue, or from *Cypridina hilgendorfii* and firefly. Light emission ceased in vacuum but reappeared on admission of air, thus demonstrating the necessity for oxygen. The only previous report of a Luciferin Luciferase reaction in fish luminescence (HICKLING 1925, 1926) is open to question because luminous bacteria have since been cultivated from the luminous organ (HANEDA 1938, 1951). The present results constitute the first clear demonstration of this reaction in fish.

In June 1958 the author had the opportunity to observe luminescence in *Apogon ellioti* (family Apogonidae) at Kochi City's Mimase base port for deep water trawl boats.

The first report on a luminous apogonid, was made by KATO (1947). He reported the possession by *Apogon marginatus* of three organs on the bend of the intestine and on either side of the rectum before the anus. IWAI and ASANO (1958) found similar luminous organs on *Apogon ellioti* and concluded that the nominal species *A. marginatus* is identical with and predated by *A. ellioti.*

Apogon ellioti is provided with three peculiar luminous ducts: one, shaped like a small bag and a beautiful lemon yellow in color, is attached to the second bend of the intestine and lie in the translucent keel muscle (anterior luminous duct); and the other two, a pair of bean-like appearance, which lie in the muscle on either side of the rectum immediately before the anus (posterior luminous ducts). Each duct is glandular in structure and all three open into the intestine. The light emission of each of three ducts is diffused respectively through an area of translucent muscle, by means of reflectors.

In a 75 mm long fish, the anterior duct is about 2.5 mm. in length, 2.2 mm. wide, and 2.0 mm. thick; and the posterior duct is 2.8 mm. in length, 1.5 mm. wide, and 0.5 mm. thick.

Attempts to cultivate luminous bacteria by usual methods from the luminous ducts of 20 specimens gave negative results. As described above, the first clear example of a Luciferin-Luciferase reaction produced solely of fish elements was demonstrated with extracts of *Parapriacanthus beryciformes.*

A second example is reported herewith, produced of extracts of either the anterior or the posterior luminous duct of *Apogon ellioti,* which extracts are found to produce light-emitting cross-reactions with partially purified Luciferin and Luciferase of the ostracod crustacean, *Cypridina hilgendorfii* and *Parapriacanthus beryciformes.*

Extracts of fresh or desicated anterior and posterior luminous ducts cross-react with each other, but not with extracts of nonluminous tissues or of the luminous organ of the firefly, *Luciola lateralis.*

Some of the results of the biochemical research conducted upon these luminous substances were reported upon by Dr. JOHNSON at the general scientific meeting held at the marine biological laboratory, Woods Hole, Massachusetts on August 20—28th 1958, in a talk entitled "Luciferin-Luciferase extracts of a fish, Apogon marginatus, and their cross—reactions with those of a crustacean, *Cypridina hilgendorfii* as a collaborative work of HANEDA, Y., Frank H. JOHNSON and EDWARD H.—C. SIE."

Large-quantity collections of dried luminous ducts of *Apogon ellioti* are now continuously being made at the Mimase base port for trawl fishing boats, Kochi City.

Crude *Apogon* Luciferin dissolves poorly in cool water but readily in methanol, giving a solution of yellow color. Studies on spectroscopy, chromatography, and possible co-factors of the *Apogon* system are in progress.

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STUDIES ON THE FISH COMMUNITY FROM THE VIEWPOINT OF DIET IN THE EASTERN PART OF THE INLAND SEA OF JAPAN

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Yoshiya Takahashi** and Yoshiaki Yamaguchi**

I Studies on the Plankton Feeders Caught by the Bottom Trawl

Several factors should be taken into account in investigating the feeding habit of the fishes which are usually classified as plankton feeders. Examination of the contents of the digestive tract involves special technical difficulties in the case of these fishes, because the food of these fishes is generally minute in size and often fragile in structure. Since the digestive tract contents of these fishes often vary according to the type of the fishing gear employed for catching, it is necessary to consider not only the time, locality and depth of catching but also the catching method, when collection of sample fishes is planned and when the results of the analyses of digestive tract contents are interpreted. In addition, certain aspects of the feeding habit of these fishes cannot be clarified without carrying out rearing experiments.

The purpose of the present study is to investigate the feeding habit of the plankton-feeding fishes caught by a two-boat bottom trawl, but the method is limited to the examination of digestive tract contents. Attention should be drawn to the fact that the material of this study was taken with a bottom gear, because the feeding habit of plankton-feeding fishes has hitherto been studied chiefly of the material taken with the fishing gears operated near the surface of the sea, such as the purse seine.

(1) Material and Method

During September 9–12, 1957, a two-boat bottom trawl conducted eight hauls in the three regions in the eastern part of the Inland Sea, namely, Kii Strait, Osaka Bay and Harima Nada. The size and power of each of the twin trawlers were 30 tons and 70 HP. The locations of the hauls are shown in Fig. 1 and the date and time of the hauls are indicated in Table 1. The sample fishes taken out of the catches of these hauls constitute the material of the present study.

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Fig. 1. Locations of hauls

Table 1 Records of Hauls

Station No.	Sea Region	Date	Time of Haul
1	Kii Strait	Sept. 9	13:28 — 14:30
2	„	„ 9	15:00 — 16:00
3	Osaka Bay	„ 10	09:30 — 10:30
4	„	„ 10	11:00 — 12:10
5	Harima Nada	„ 11	09:15 — 10:20
6	„	„ 11	12:20 — 13:20
7	„	„ 12	09:30 — 10:30
8	„	„ 12	12:40 — 13:40

The sampling was carried out as soon as the net was hauled aboard, and the specimens were immediately fixed in 10% formalin. A total of 1,221 specimens of plankton-feeding fishes (representing 15 species) were collected (Table 2). The fixed specimens were later examined in the laboratory, when the following items were covered in each specimen: species name, total length, body length, body weight, sex, weight of gonads, 'gross weight' of the digestive tract (the weight of the digestive tract from oesophagus to anus as containing its contents) and weight of viscera. The 'gross weight' of the digestive tract was

Table 2 Number and body length range of fish specimens

Species	Number	Body Length (mm)
Trachurus japonicus (T. et S.)	469	77~120
Apogon lineatus (T. et S.)	156	47~ 71
Leiognathus rivulatus (T. et S.)	377	36~ 69
Callionymus lunatus T. et S.	7	90~114
Upeneus bensasi (T. et S.)	10	67~ 85
Neopercis sexfasciata (T. et S.)	2	112
Sillago sihama (Forskål)	8	114~129
Trichiurus lepturus Linné	1	270
Bathygobius fuscus (Rüppell)	1	95
Argyrosomus argentatus (Houttuyn)	8	70~ 77
Acanthocepola krusensterni (T. et S.)	24	154~360
Cryptocentrus filifer (Cuvier et Valenciennes)	35	89~116
Engraulis japonica (Houttuyn)	2	97
Psenopsis anomala (T. et S.)	88	99~146
Lagocephalus lunaris (Bloch et Schneider)	17	70~132

measured to mg. The contents of the digestive tract were examined in 125 specimens (54 *Trachurus japonicus*, 49 *Leiognathus rivulatus*, 25 *Apogon lineatus*, and 51 specimens belonging to other 12 species). The method of the examination was as follows. The digestive tract was divided into several portions, the contents of the different portions were washed into separate glass dishes, and each portion was weighed to mg. after thus emptied ('net weight' of the digestive tract). The whole material in the glass dish was examined under the microscope, when the food organisms were identified to genera or species and, if feasible, their numbers or sizes were recorded.

The present report deals with the results on the three species (*Trachurus japonicus*, *Leiognathus rivulatus* and *Apogon lineatus*) which predominated in the catch throughout the three regions.

(2) Weight of Digestive Tract and of its Contents

In Fig. 2 the 'gross weight' and 'net weight' of the digestive tract (respectively indicated by ● and ○) in the specimens of *Trachurus japonicus*, *Leiognathus rivulatus* and *Apogon lineatus* are plotted against the body length of the fish. The 'gross weight' was measured in all specimens, while the 'net weight' was measured only in those specimens the digestive tract contents of which were examined. By inspecting Fig. 2, one can roughly estimate how much weight an

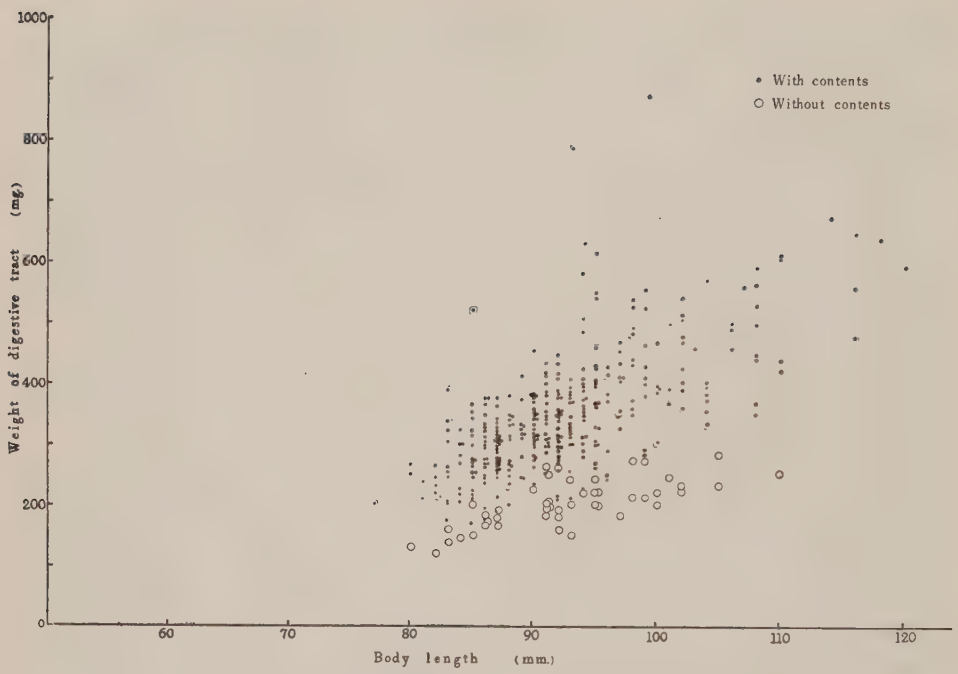

Fig. 2–1. Weight of digestive tract with and without contents
Trachurus japonicus

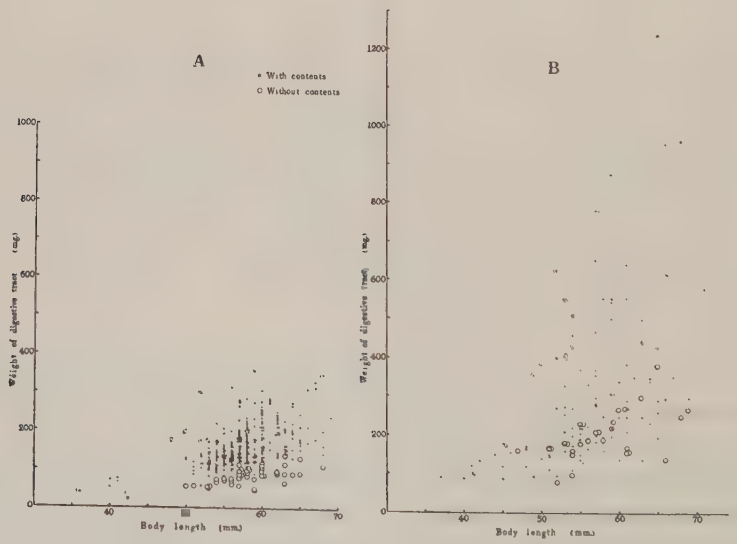

Fig. 2–2. Weight of digestive tract, with and without contents
A. *Leiognathus rivulatus* B. *Apogon lineatus*

empty digestive tract of a fish will gain when the fish is fed nearly to satisfaction. On the basis of such estimate the ratio of the weight of digestive tract to the body weight and the ratio of the weight of digestive tract contents to the weight of digestive tract are computed (Table 3).

Table 3 Weight of digestive tract and its contents

Species		*Trachurus japonicus*	*Leiognathus rivulatus*	*Apogon lineatus*		
				1)	2)	
No. of Specimens		54	49	18	7	25
Average Body Weight (g)		12.86	4.22			7.00
Average Weight of Digestive Tract (W.D.T.) (mg)		212	89			208
Average Weight of Digestive Tract Contents (W.D.T.C.) (mg)		137	69	156	369	
Average of W.D.T.C./W.D.T. (%)		45.9	41.7	29.1	63.7	38.8
Frequency of Specimens by W.D.T.C./W.D.T. Classes	~10.0%		1	7		
	10.1~20.0		2			
	20.1~30.0	13	5	4		
	30.1~40.0	19	11	2		
	40.1~50.0	16	14		1	
	50.1~60.0	5	14	2	1	
	60.1~70.0		2	2	3	
	70.1~80.0	1		1	2	

1) Specimens having no egg in the stomach
2) Specimens having eggs in the stomach

(3) Composition of Digestive Tract Contents

The results of the examination of the digestive tract contents are summarized in Table 4. In this table only the major classification of the food organisms is indicated. The numerals in the table refer to the number of the fish specimens in the digestive tract of which the stated food organism was found. In examining digestive tract contents, presence or absence of a certain food organism was always recorded, but the number of the organism was counted only in a limited number of fish specimens. (In the case of "diatom", the size of the cell was measured instead of counting the number of cells.) The number of such fish specimens is indicated in the column of "Remarks". Although there is possibility that only a portion of the food present in the digestive tract was identifiable because digestion was usually in progress, the results presented in Table 4 seem to serve, to a certain extent, as a basis for considering the composition of the digestive tract contents in the three fishes under consideration.

"Copepod", "shrimp", "mysis", "fish scale", "polychaeta" and "diatom" were found in the digestive tract of all the three species. When comparison is made between the fish specimens from different regions, it is noticed that "cypris larva" is found relatively more frequently in the specimens from Kii Strait than in those from other regions. But it is difficult to point out any other notable difference associated with regions, particularly when the scantiness of the data is taken into account.

When comparison is made between the three fish species, there is an indication that the composition of digestive tract contents somewhat differed according to the species. In *Apogon lineatus*, "copepod", "bivalve larva", "gastropod larva" and "diatom" were found less frequently and the eggs of the same species more frequently than in the other two species. "Megalopa", "cypris larva" and "fish scale" were recorded more frequently in *Trachurus japonicus* than in the other species. It should be noted, however, that the occurrences of "megalopa" and "cypris larva" were limited to the specimens from particular localities. As for fish scales, it is nearly a common practice to consider that they enter into the digestive tract secondarily.

(4) Discussion

Since the data obtained through the present study are still limited in scope, it is not possible to discuss various phases of the feeding habit of the three fishes under consideration. However, that these fishes possibly feed chiefly on the plankton and nekton even when they live near the sea bottom is suggested by the fact that such a variety of food organisms as crustaceans, mollusks, polychaetes, diatoms and fishes were found in the digestive tracts of the specimens taken by a bottom trawl in Kii Strait, Osaka Bay and Harima Nada.

It is very probable that the eggs of *Apogon lineatus*, which were abundantly found in the digestive tract of the same species had been incubated in the oral cavity and entered into the stomach secondarily, because some specimens of this species were seen incubating eggs in the oral cavity. It has already been stated that the fish scales, which were found frequenly in the digestive tract of *Trachurus japonicus* and less frequenly in the same organ of other species, probably entered into the digestive tract also secondarily. Even after the secondary effects due to these two factors are eliminated, it still appears that the composition of digestive tract contents somewhat differs according to species. Such differences may be ascribable to the differences between the life types of the three species, but we are not yet certain in this respect, because the specimens for the three species were not comparable with regard to the body size. The causes of such differences and the tendency that the food of particular sizes is selectively taken are the problems to be studied in future.

According to Aoyama (1958) who studied the feeding and the progress of digestion in *Trachurus japonicus* by rearing experiments, the stomach contents weigh about 4% of the body weight in this species at the moment when the fish is so sufficiently fed that it is no more attracted by food. Suppose that a line is

drawn in Fig. 2–1 so as to depict the upper limit of the distribution of the dots (neglecting a few dots which are in the upper left somewhat apart from the other dots), that the 'net weight' of the digestive tract is substracted from the 'gross weight' indicated by this line, and that the difference is divided by the corresponding body weight. Then we obtain a ratio which is in good agreement with the one obtained by Aoyama, i.e., 4%.

All the fish specimens constituting the material of the present study were caught in the day-time, and there is no assurance that the activities of these fish were at the peak of the diurnal rythm when they were caught. But these specimens as a whole have characteristics in that they came from various parts of a relatively large sea area and were caught at different times during the day. The fact that the information derived from these specimens is in good agreement with the results of the rearing experiment may be taken to indicate that some of these fish were sufficiently active at the time of capture.

The data so far obtained do not suit the analysis of the diurnal change of the weight of digestive tract contents. But there is indication that the weight of the digestive tract containing the contents somewhat differs between the *Trachurus japonicus* specimens from St. 1 (Kii Strait) and those from St. 4 (Osaka Bay) (Fig. 3). The cause of this difference is not yet clarified. It is

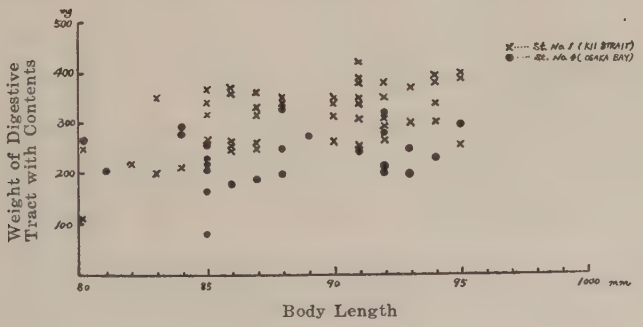

Fig. 3. Weight of digestive tract with contents in *Trachurus japonicus* (T. et S.) taken in two different sea regions.

expected that the cause of this difference, and more generally the interrelation between the feeding of the predators and the behavior of the food organisms, will be clarified by examining more specimens caught under various conditions.

Table 4—1. Composition of food in digestive tract

Trachurus Japonicus (T. et S.)

Sea Region		Kii Strait		Osaka Bay		Harima		Nada		Total	Remarks
Station No.		1	2	3	4	5	6	7	8		
No. of Specimens		36	2	3	6	4		2	1	54	
Total of Body Weight (gr)		436.8	24.6	55.3	71.0	58.6		32.0	17.5	695.8	
Total of Weight of Digestive Tract Contents (mg)		4425	268	766	459	799		466	192	7375	
Crustacea	Copepod	32	2	2	6	4		2	1	49	7
	Phyllopod										
	Shrimp & Mysid	30	2	3	5	4		2	1	47	1
	Zoea	3								3	
	Megalopa	23	2							25	1
	Cypris Larva	21			1					22	15
Mollusca	Octopod										
	Bivalve Larva	8	6							14	9
	Gastropod Larva	8	3							11	4
Pisces	Scale	19	2		5			2		28	27
	Egg										
	Fish										
Polychaeta		14	1		3					18	
Diatom		7	1	2		2			1	13	10
Sand		1								1	
Others								1*		1*	* Fragments of Cellophanes

Table 4—2. Composition of food in digestive tract

Leiognathus rivulatus (T. et S.)

Sea Region		Kii Strait		Osaka Bay		Harima		Nada		Total	Remarks
Station No.		1	2	3	4	5	6	7	8		
No. of Specimens		25	5		2	4	5	5	3	49	
Total of Body-weight (g)		105.6	22.7		9.1	15.7	20.9	18.7	14.2	206.9	
Total of Weight of Digestive Tract Contents (mg)		1550	397		48	330	424	256	390	3395	
Crustacea	Copepod	23	5		1	4	5	4	3	45	16
	Phyllopod										
	Shrimp & Mysid	15	2		2	3	5	2		29	
	Zoea		1							1	1
	Megalopa		2				3			5	1
	Cypris Larva		2							2	2
										1	
Mollusca	Octopod										
	Bivalve Larva		2							2	2
	Gastropod Larva	3	2							5	4
Pisces	Scale		1				1			2	1
	Egg								1	1	
	Fish										
Polychaeta		7	3				3	1	2	16	5
Diatom		9	3			1	2	1	3	19	18
Sand											
Others		1*								1*	* Fragments of Cellophanes

Table 4—3. Composition of food in digestive tract

Apogon lineatus (T. et S.)

Sea Region		Kii Strait		Osaka Bay		Harima		Nada		Total	Remarks
Station No.		1	2	3	4	5	6	7	8		
No. of Specimens		10	5		1	2	1	4	2	25	
Total of Body-weight (g)		60.9	42.6		7.8	10.3	6.5	30.4	16.6	175.1	
Total of Weight of Digestive Tract Contents (mg)		1119	1542		636	305	102	1270	467	5440	
Crustacea	Copepod		1					1		2	2
	Phyllopod										
	Shrimp & Mysid	5	1			2	1	3	2	14	8
	Zoea										
	Megalopa										
	Cypris Larva										
Mollusca	Octopod										
	Bivalve Larva										
	Gastropod Larva										
Pisces	Scale		2					1		3	3
	Egg	1**	4**		1**			1**		7**	** Egg of *Apogon lineatus*
	Fish										
Polychaeta		8	3							11	1
Diatom			1					1		2	2
Sand											
Others											

II On Food Niches of the Dominant Piscivorous Lizard Fish of Genus Synodus and Genus Saurida on the Continental Shelf Along the Pacific Coast of Tokushima Prefecture, as a Preliminary Study to Analyse the Food Niches in Higher Consumer Level of the Marine Community through Stomach Contents Analysis.

It seems that the trophic relations in marine animal community around this region have complex features and food niches of the members of the community can not be described simply.

Here the present authors analysed preliminarily the food niches of two dominant voracious fishes through their stomach contents to find some methods for the orientation of food niches in higher consumer level of the animal community on the continental shelf along the Pacific coast of Tokushima Pref., in Shikoku Is., Japan.

So-called lizard fish "ESO" are dominant benthic-piscivorous ones in this region and include the three species of genus Saurida and the one species of genus Synodus. These fishes have generally their own habitat ranges but this does not mean that they always segregate their habitats from each other, as is seen in Fig. 4. They live more or less together in this region all the year round as the results of partial overlap of their distributions of populations. They vary their abundance, their size, and consequently the ecological relations among themselves by seasons.

These lizard fishes resemble to each other in their body shapes, body organizations, internal structures, and mechanisms for taking and digesting their foods.

The authors made at first the comparisons between the sizes of common prey of two genera and then between their life forms. The discussions were made on the food niches of these predators in this region and briefly on the prospect of further studies on food niches of these higher consumers.

(1) Materials and Method

The species of predators here dealt with are as follows:

Order Myctophida
Suborder Myctophina
Family Synodontidae
GENUS SYNODUS
Synodus macrops TANAKA : "CHOCHO-ESO"
GENUS SAURIDA
Saurida undosquamis (RICHARDSON) : "MA-ESO"
Saurida tumbil (BLOCH) : "WANI-ESO"
Saurida elongata (TEMMINCKE et SCHLEGEL) : "TOKAGE-ESO"

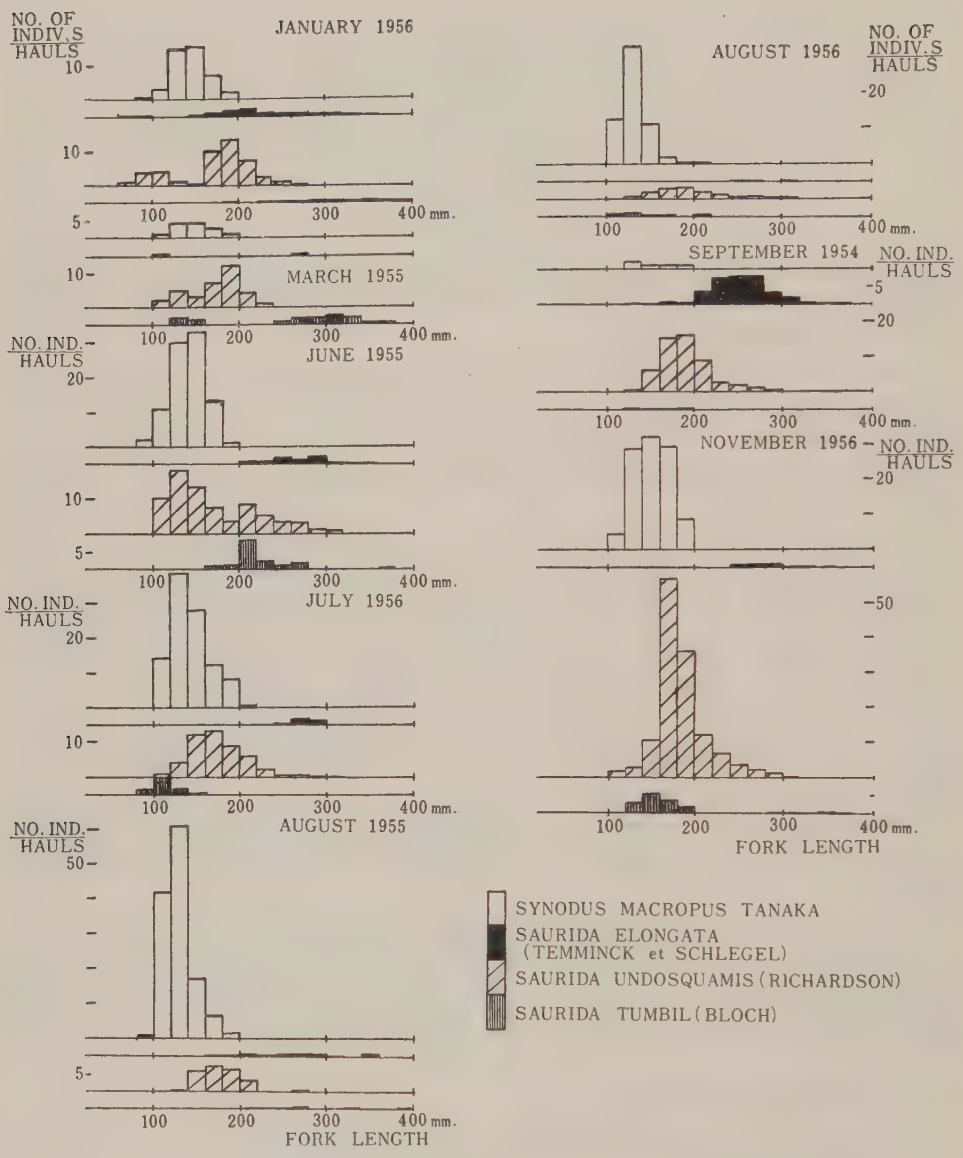

Fig. 4. The body size frequencies (in fork length) of "Lizard Fishes" per one haul of trawl nets operated seasonally.

Materials of these fishes are the samples taken seasonally by 2-boat trawler of medium size (30 tons and 70 HP.) on the continental shelf along the Pacific coast of Tokushima Pref., of which the four sets of samples, taken in July 1956, August 1955, August 1956, and November 1956, were selected for this study because of the ample numbers of individuals of them for detailed stomach

contents analysis through these two genera. Each set of samples contains those by net-hauls of several times.

Samples were immersed in 10% formalin solution when they were brought on deck of the trawler. Measurements and dissections on each individual of samples were done in laboratory in the Inland Sea Regional Fisheries Research Laboratory. Besides the measurements on body size (fork length), body weight, gonad weight, and the identification of sex, stomach contents were identified and weighed after each mass of discernible individual, and then the fragmental hard part of the residual mass which was found in the stomach were also measured as far as possible. This last measurement is of use to restore the original size of victims, converting by the regression line, prepared in other studies, between the length of specific part of body and the whole size of body. In this study, the regression line between the length of columns of six vertebrae, which follows after the 1st haemal spine, and the total length of body size of the dominant prey, *Champsodon snyderi* (FRANZ), is used to restore the body size of this prey individual found in the stomachs, and it could be expressed approximately as follows: V.L.=0.125 T.L., where V.L. and T.L. are the length of those columns of six vertebrae and the total length of *Champsodon snyderi* in mm., respectively.

Such informations were arranged here after every body-size group of predators, such as 181–200 mm. group, 201–220 mm. group and so on in fork length, where three species of genus Saurida were treated as one category because of the similar characters as predator according to the result obtained by other studies. And the frequencies of total lengths of the prey, *Champsodon Snyderi,* restored as shown above, were arranged in class-intervals of 10 mm.

(2) Result

Prey-size—Among the samples which were taken in November 1956, there were many individuals of similar body size through both predators, which, at the same time, had numerous individuals of the prey species, *Champsodon snyderi,* in their stomachs. The size frequency of restored total length of this common prey species found in the stomachs of each predator was compared to each other at every body-size group of predators, as shown in Fig. 5–a. On the other hand the aggregated size frequencies on the same data were compared in the same way as shown in Fig. 5–b.

From these two figures, those facts are observed that the larger predator feeds on larger *Champsodon snyderi* through both genera and *vice versa,* and each of the predators of the same size groups feeds on this prey of the similar size frequencies, with one exception in the case of 121–140 mm. groups of the predators.

Composition of food items—Here was analysed whether or not both predators feed actually on the similar prey items in the same circumstance. For this purpose the degrees of appearances (n/N) of each food item found in the

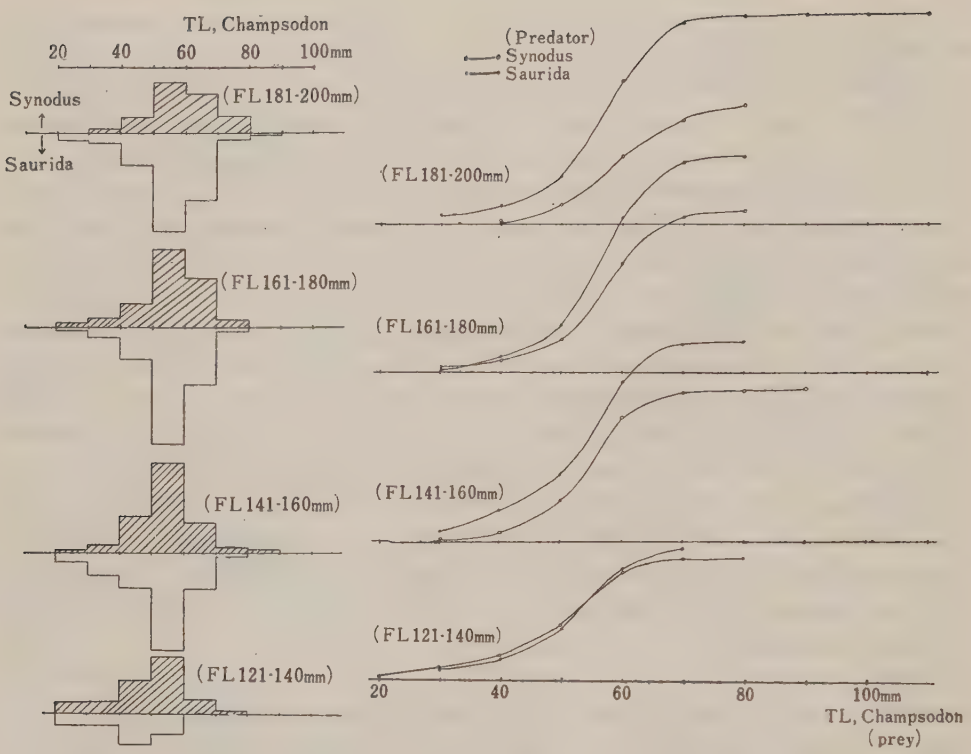

Fig. 5. Restored size frequencies of the dominant prey, *Champsodon snyderi*, found in the stomachs of genus Synodus and genus Saurida of 4 size groups taken in November 1956.

Fig. 5–a. Size frequencies of the prey in every size group of predators, represented by upper or lower one, genus Synodus or genus Saurida respectively.

Fig. 5–b. Aggregated size frequencies of the prey in every size group of these predators.

stomachs were compared between both predators at every size group of predators, where N and n are the numbers of individuals of predator of any size group and the numbers of individuals of a certain prey animal found in the stomachs of N individuals of predator.

Results of these comparison on the data from the samples collected in July 1956, August 1955, and August 1956 are shown in Fig. 6.

Although prey items found in the stomachs of predators resemble closely to each other in general, some differences between these two genera were observed in the compositions of prey items:—

Anchovy (*Engraulis japonica* (HOUTTUYN)), horse-mackerels (Fam. Carangidae), and *Bregmaceros japonicus* (TANAKA) generally tend to be appeared more often in the stomachs of genus Saurida than those of genus

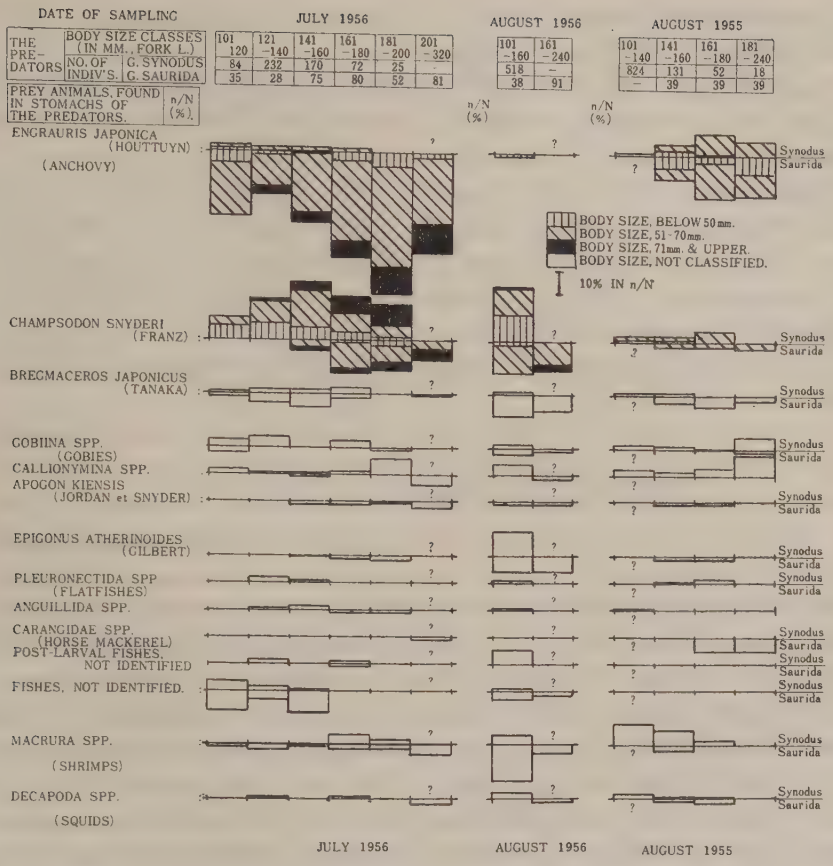

Fig. 6. The Comparisons of the appearances of main prey animals found in the stomachs of the two genera of lizard fishes between the same size groups of genus Synodus and genus Saurida.

The degree of appearance (n/N) is indicated in figure by vertical height of column in upper or lower direction, representing that of genus Synodus or genus Saurida respectively, where n=(numbers of prey individuals found in the stomachs of predator of a certain body size) and N=(number of predator individuals of the corresponding body size)

Synodus of every size group. *Champsodon snyderi* (FRANZ), Calionymus fishes (Suborder Callionymina), flatfishes (Order Pleuronectida), gobies (Suborder Gobiina), and larval forms of fishes, not identified, on the contrary, are generally tend to be appeared more often in the stomachs of genus Synodus than those of genus Saurida of every size group.

(3) Discussion

Preference for prey-size—The fact that the larger predator feeds on larger prey through both predators would come from the common habitual character

of those predators: namely, these predators have the preference for the size of prey in relation to the size of predator.

The other fact that each of the predators of similar size feeds on prey of the similar size frequencies would also come from the similar abilities through both predators to pursue their prey.

From these results obtained on prey size in relation to the size of predator, the authors may safely state that they pursue the prey of the same size while each of the predators has the similar prey-size-dependent preference for their prey to each other in such a circumstance where both of the predators prey mainly on *Champsodon snyderi*.

Consequently it seems that they behave similarly as predator in the size relation of predator-prey.

Life form—First of all the common characters as predator through both genera would be observed from the fact that the prey items found in the stomachs of co-exisiting predators resemble closely to each other as a whole. These features would come from the benthic life form and the voracious character of these piscivor in general.

But among the differences which were observed between the compositions of prey items of these two genera, the following facts would be meaningful in respect to the habitual tendencies of these predators:—

Anchovy and horse-mackerel, which were found more often in the stomachs of genus Saurida than in those of genus Synodus, are the fish caught ordinarily by the commercial fisheries of purse-sein nets, boat drag nets and other fishing gears for "pelagic fish", and ocassionally by those of trawl nets and other fishing gears for "benthic fish". On the other hand, flatfishes, Callionymus fishes, and gobies, which were found more often in the stomachs of genus Synodus than in those of genus Saurida, are almost caught by the fishing gears for "benthic fish".

Although some disagreements in the appearances of larval forms of unidentified fishes and *Bregmaceros japonicus* (TANAKA) which were observed in the stomach contents and the disagreement of size frequencies of *Champsodon snyderi* which are found in the stomachs of the 121–140 mm. group of predators could not be attributed to the essentially different characters of those predators as far as the present informations concern, the related informations on the appearances of the specific prey animals in the stomachs of predators and on the characters of fishing gears which catch the corresponding animals as commercial catches would suggest to us some characteristic difference of life form between these two predators when they live together in the same circumstances.

Consequently it seems that the life form of genus Synodus is more benthic than that of genus Saurida.

Food niches—After these analysis on stomach contents of the two dominant genera of piscivorous fishes on the continental shelf along the Pacific coast of Tokushima Pref., the food niches of these fishes would be expressed as follows.

They behave similarily in their preferences for the prey-size and also in their benthic characters as a whole, but do differently in detail, showing that genus Synodus behaves more benthic than does genus Saurida as predator.

It will be noted here that, in the other studies for the orientation of food niches of these and other predators which belong to the higher consumer level in the community around the coastal region of Inland Sea and its adjacent area, the authors come to the similar conclusion that the predator has a preference for its prey-size depending on the size of itself, and food niches of predator will be expressed in simple form in the combination of the preference for prey-size and the life form. The further numerical trials to abstract the prey-size-dependent preference of each predator from the informations on stomach contents will be dealt with in future studies.

III A Study of Interspecific Association.

(1) Introduction

One of the features of Japanese fisheries is that almost all the landings have more or less market values regardless of their species and sizes. Non-selective fisheries such as coastal trawlers take Pisces, Brachyura, Anomura, Macrura, Octopoda and Decapoda. Therefore, what the fisherman is principally concerned with is how effectively to exploit the mixed stocks consisting of many species.

Significance of the community study in fisheries research has been appreciated by many workers and most of their works are centered on how to measure and express its construction. In this report, the authors attempted to analyse the structure of association by the composition of species of trawl catches in some area and to make a picture of interspecific association, using the correlation method which has been used in the analysis of forest structure.

(2) Material

Data used here were obtained from the bills of one of the commercial fishermen operating on the narrow continental shelf off-shore of Mugi, Tokushima Prefecture, where the catch of about six hauls was landed daily. We can know the components of one day's catch, species and their quantities. Those obtained in September and November in recent five years, totaling 97 operating days, were used for this study. As shown in Table 5, the total number of species appeared is 53, of which 42 species on order of quantity are taken for discussion.

(3) Method

It may be reasonably assumed that during September and November-season the fish-community in this sea-area has the same construction every year and there are 97 quadrate samplings from this area, because the locations of the hauls in one day were not far apart from each other. From the results of these quadrate samplings, the interspecific relation was analysed by means of the 2×2 table to give presence or non-presence number of any two given species in the same quadrate.

Table 5. List of species appeared and its catch.

( ): Japanese name.

(( )): Colloquial name of which Japanese name is indistinct.

No.	Species	Japanese name	Catch (Kan)
1	Psenopsis anomala	(ibodai)	2911.860
2	Malakichthys griseus	(ōmehata)	1554.000
3	Saurida spp.	(eso)	1346.625
4	Lophiomus setigerus	(ankō)	1082.900
5	Argentina semifasciata	(nigisu)	782.100
6	Branchiostegus japonicus japonicus & Branchiostegus japonicus auratus	(amadai)	744.295
7	Pleuronectida spp.	(karei)	637.150
8	Taius tumifrons	(kidai)	533.760
9	Lepidotrigla spp.	(kanagashira)	532.300
10	Chelidoperca hirundinaces	(himekodai)	496.300
11	Caranginae spp.	(aji)	427.030
12	Macrura spp.	(ebi)	377.230
13	Nemipterus virgatus	(itoyoridai)	325.105
14	Sebastinae spp.	(mebaru)	312.900
15	Muraenesox cinereus	(hamo)	285.275
16	Zeus japonicus	(matōdai)	268.450
17	Synodus macrops	(chōchōeso)	246.000
18	Sphyraena spp.	(kamasu)	234.460
19	Decapoda spp.	(ika)	229.360
20	Chelidonichthys spp.	(hōbō)	195.070
21	Doerleinia berycoides	(akamutsu)	172.550
22	Synchiropus altivelis	(beniteguri)	159.200
23	Uranoscopus japonicus	(mishimaokoze)	143.350
24	Ibacus ciliatus	(uchiwaebi)	143.000
25	Trichiurus lepturus	(tachiuo)	131.430
26	Scombrops boops	(mutsu)	115.450
27	Congridae spp.	(anago)	104.485
28	Upeneus bensasi	(himeji)	103.240
29	Rajina spp.	((manto))	97.300
30	Platycephalicae spp.	(kochi)	94.750
31	Ophichthidae spp.	((dōji))	82.250
32	Argyrosomus argentatus	(shiroguchi)	80.850
33	Chrysophrys major	(madai)	74.620
34	Decapoda spp.	((mizuika))	70.900
35	Caranx equula	(kaiwari)	61.350
36	Sepia esculenta	(kōika)	58.150
37	Chlorophthalmus albatrossis	(aomeeso)	54.150
38	Lamnida spp.	(same)	48.575
39	Rajina spp.	(ei)	45.650
40	Fugu rubripes	(torafugu)	40.200
41	Evynnis japonica	(chidai)	33.200
42	Brotulidae spp.	((namazu))	15.150
43	Branchiostegus argentatus	(shiroamadai)	11.360
44	Rhinobatos schlegeli	(sakatazame)	4.200
45	(indistinct)	((gagane))	4.100
46	(indistinct)	((tengu))	4.000
47	Tetraodontidae spp.	(fugu)	3.600
48	Fistularis spp.	(yagara)	3.400
49	Pleuronichthys cormutus	(meitagarei)	3.300
50	Octopoda spp.	(tako)	2.450
51	(indistinct)	((hota))	1.050
52	Paralichthys olivaceus	(hirame)	.750
53	Pampus argenteus	(managatsuo)	.550

If species A and species B distribute randomly to each other in the same unit mentioned above (Table 6.), the number of samples in the series in which both species would be expected to occur together is $\frac{(a+b)(a+c)}{n}$.

Table 6. Arrangement of a 2×2 table for testing association between species.

Species A	Species B		
	present	absent	
Number of times present	a	b	a+b
Number of times absent	c	d	c+d
	a+c	b+d	a+b+c+d=n

On the other hand, the test of statistical significance in a 2×2 table is easily performed by means of Chi-square test, there being a single degree of freedom in such a table. The Chi-square is computed by the formula:

$$\chi^2 = \frac{\left(ad-bc\pm\frac{n}{2}\right)^2 n}{(a+b)(a+c)(c+d)(b+d)}$$

When the number of realized joint-occurrence in the sampling series is above its expected value under null hypothesis of independence and significant in Chi-square test, it means that there is a habitat-integration relationship between this two species and when its number is significantly below the expected one, it means presence of a habitat-segregation relationship. If it is insignificant in the test, it can be seemed to distribute randomly to each other. To the given marginal number in a 2×2 table, the maximum and minimum values of a are necessarily defined. Cole (1949) defined his association index between two species as a ratio of realized value of a to the maximum value or minimum one which is possible to a, calling it zero association when realized a is insignificant in the test, namely, they distribute randomly to each other, positive association when realized a is significantly above the expected one, and negative association when realized a is significantly below the expected one. Figure 7 shows all these relationships between any two given species in which ○ means habitat-integration, × habitat-segregation and others random distribution. The names of species were arranged in order of Cole's Index, +1 to −1, to *Argentina simifasciate* KISHINOUYE (nigisu).

On the other hand, computing correlation coefficient r between the quantities of any two species in the catch of one quadrate and testing the hypothesis $\rho=0$, we might assume the inclusive relation between such species when r is positive and significant in the test, exclusive one when r is negative and significant, and random relation when insignificant. Figure 8 shows all these relationships corresponding to Figure 7.

They do not agree completely, the association expressed as species presence and non-presence in the quadrates and the one expressed as correlation of species biomass in the quadrates. These differences were shown in Table 7 about all 861 combinations between any two given species, in which are used the symbols such as (+, −) which means significantly positive in Cole's Index and significantly negative in the coefficient of correlation between the two species. The ecological meaning of each cell in Table 7 is as follows:

(+, +) : They are in a habitat-integration relationship about their living area and each species biomass is inclusive too within the area.

(+, −) : They are in a habitat-integration relationship about their living area but its species biomass is exclusive within the area to each other.

(+, insig.) : They have only the common habitat and have not direct ecological connections to each other.

(−, −) : They have quite different habitats.

(−, insig.) : They distribute segregatively but share the common habitat locally, showing no direct ecological connections.

(insig., +) : The distributions of two species distribute randomly to each other but the distribution of their biomass inclusive.

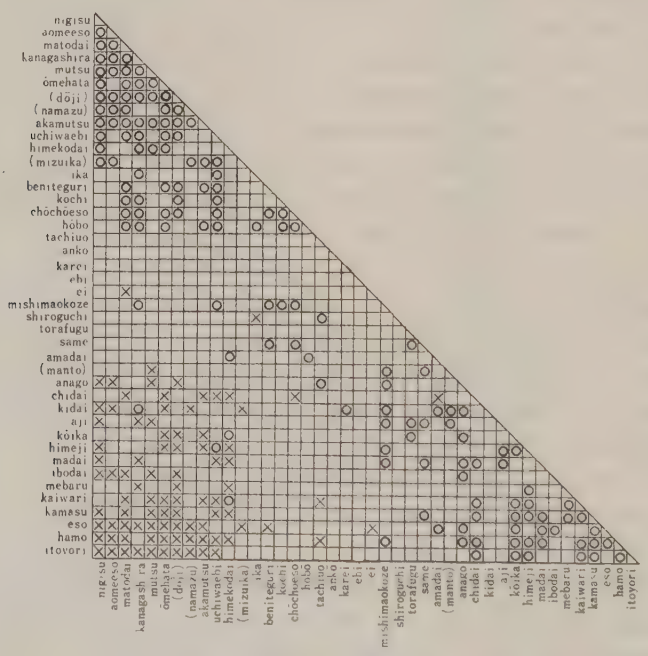

Fig. 7 Association between any two given species.
Significant association in Chi-square test.
○: habitat-integration
×: habitat-segregation

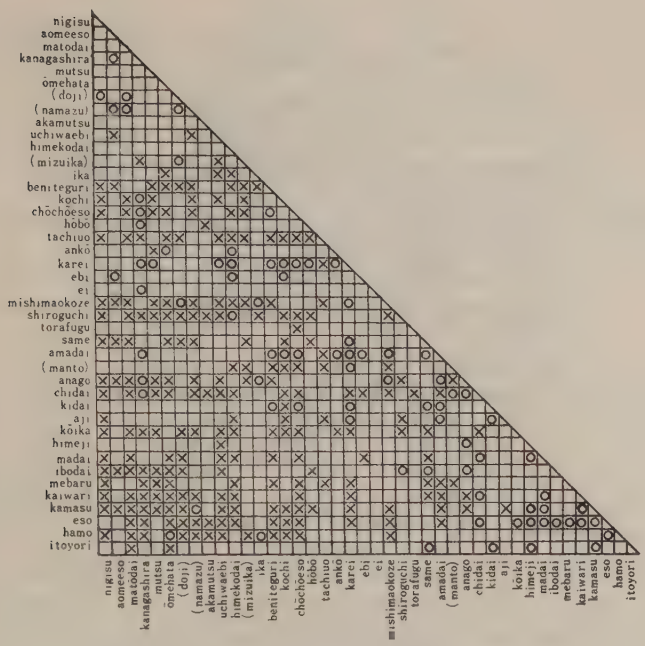

Fig. 8 Correlation in the catch between any two given species.
Significant correlation in the hypothesis of $\rho=0$.
○: + correlation (habitat-integration)
×: − correlation (habitat-segregation)

(insig., −) : Inversely mentioned above, the distribution of their biomass exclusive.

(insig., insig.) : The distributions of two species and its biomass distribute randomly and temporaly.

Table 7. Comparison of two approaches.

			Coefficient of correlation: r			
			significant		insignificant	total
			+	−		
Coefficient of association	significant	+	3.3 % (28)	1.9 % (16)	11.9 % (102)	17.0 % (146)
		−		5.8 (50)	4.5 (39)	10.4 (89)
	insignificant		6.1 (52)	19.4 (167)	47.4 (407)	72.8 (626)
	total		9.3 (80)	27.1 (233)	63.8 (548)	100.0 (861)

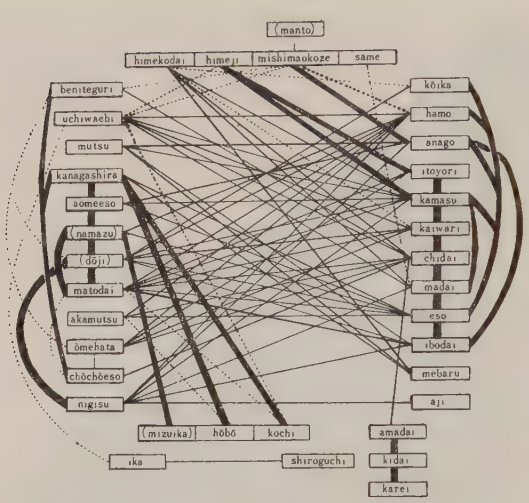

Fig. 9 Interspecific associations which are significant in both approaches.
thick lines: (+, +)
solid lines: (−, −)
broken lines: (+, −) (see text)

The picture of interspecific associations of (+, +), (+, −) and (−, −) from Table 7 was shown in Figure 9 in which thick lines represent (+, +); broken lines (+, −) and solid lines (−, −).

(4) Discussion

The following questions may be raised against the methods mentioned above:

1. It may be a question whether hauls in one day have concentrated in one point. Practically it is the case but on rare occasions, when its haul's catch is poor, the fisherman might go to other places and the results might have been disturbed.
2. The results depend on its size of sample unit and are changeable by the size of unit to some extent.
3. Because the data were obtained from the bills at fisheries market, it is possible that the small catches below some standard, depending on the price of the species, might have been neglected.
4. In connection with the point 3, it must be considered that in this report the miscellaneous fishes recorded on the bills were neglected in the computation because its species compositions were indistinguishable.
5. To analyse the construction of fish community, it is required to investigate for each species food habitat, food competition and prey-predatorship etc. at the same time and the method mentioned above would be valid combined with these informations.

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in Japan. (Special Number 3)
October 1959

BIOLOGY OF THE JAPANESE ANCHOVY, *Engraulis japonica* (HOUTTUYN), IN THE NANKAI REGION. I

By

Kōji Takeshita and Hiroaki Aikawa

Among the Japanese anchovy there are seasonally two groups. *Aikawa* (1950, '54), *Yokota* et *Furukawa* (1952), *Asami* et *Hanaoka* (1957) and many other authors stated that these two groups are different from each other in the vertebral number and that these two are considered as different races respectively. Mingling, probably, with each other during development and aslo in fishing, there arise many errors in distinguishing the races based on the vertebral number throughout the development from brood to adult. Hence, some characters other than the vertebral number must be employed for racial analysis.

Present authors tried to analyze the race based on the size of marks formed

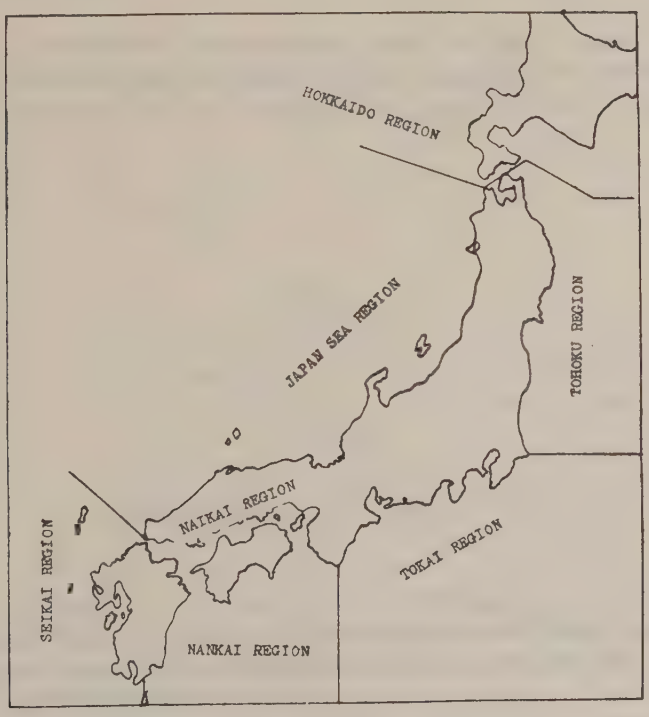

Fig. 1. Water-regions around Japan.

on the scale, and verified its validity from comparing the results with those based on the vertebral number.

The specimens examined amounted to 1098 fishes among 2000 sampled from the catches throughout the regions around Japan, mainly in the Nankai region since 1953. In addition, some data on the vertebral number are referred to the reports issued from several regional fisheries institutes.

1. The vertebral number

The simple average of vertebral number, as a racial character, cannot indicate the variation type itself which is usefully applied to discriminate the race in the present report.

The vertebral number of the Japanese anchovy varies from 42 to 47 pieces, mostly between 44 and 46, having a mode in 45, not only in almost all samples but as a whole. Here, taking 45 pieces as a standard, percentage frequencies of the individuals provided with the pieces more than 45 and of those with pieces less than 45 are calculated in each sample. And, by testing with the confidence limit (Pr. 90%), there are found three groups: (1) number of individuals with pieces more than 45 are significantly more dominant than those with less than 45, that is, *V*-group; (2) both are not significantly different from each other and (3) the former is smaller than the latter is, those in last two cases are called here *v*-group together, as the case (3) is found only in 10 samples among 533.

There is found only one peak in frequency distribution of the average vertebral number, so far concerning the size group under 50 mm. in body length in the Nankai region, by using the data from Report B issued from Nankai

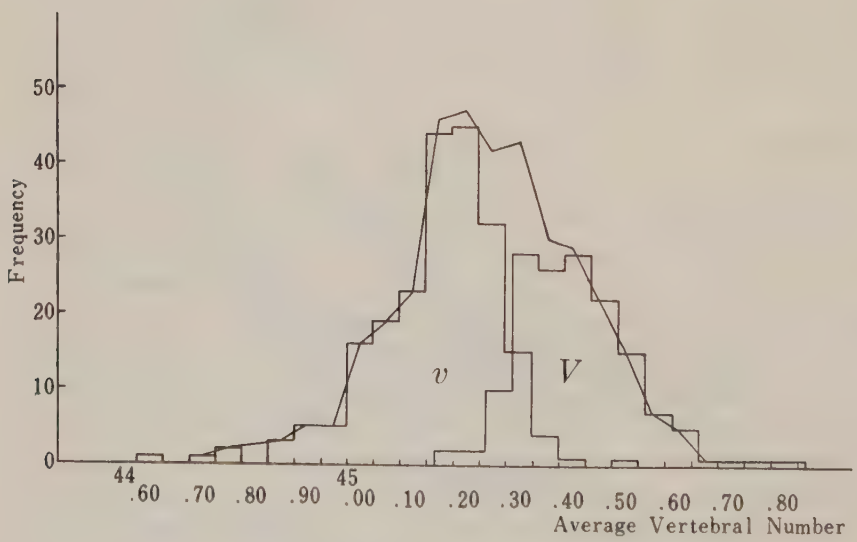

Fig. 2. Frequency distribution of average vertebral number in *v*- and *V*-groups.

Regional Fisheries Research Laboratory, about the sample more than 20 individuals in sample size. This unimodal group comprises *V*- and *v*-groups, each of which is bordered on the average vertebral number of 45.25 from each other and has a mode respectively (Fig. 2).

From tracing the monthly change in the relative frequencies of *V*- and also *v*-groups, it is found that while *V*-group is dominating in the former half of year, especially in March and April, *v*-group is dominant in the latter half (Fig. 3a). Then, *V*-group is originated from spring brood group, while *v*-group

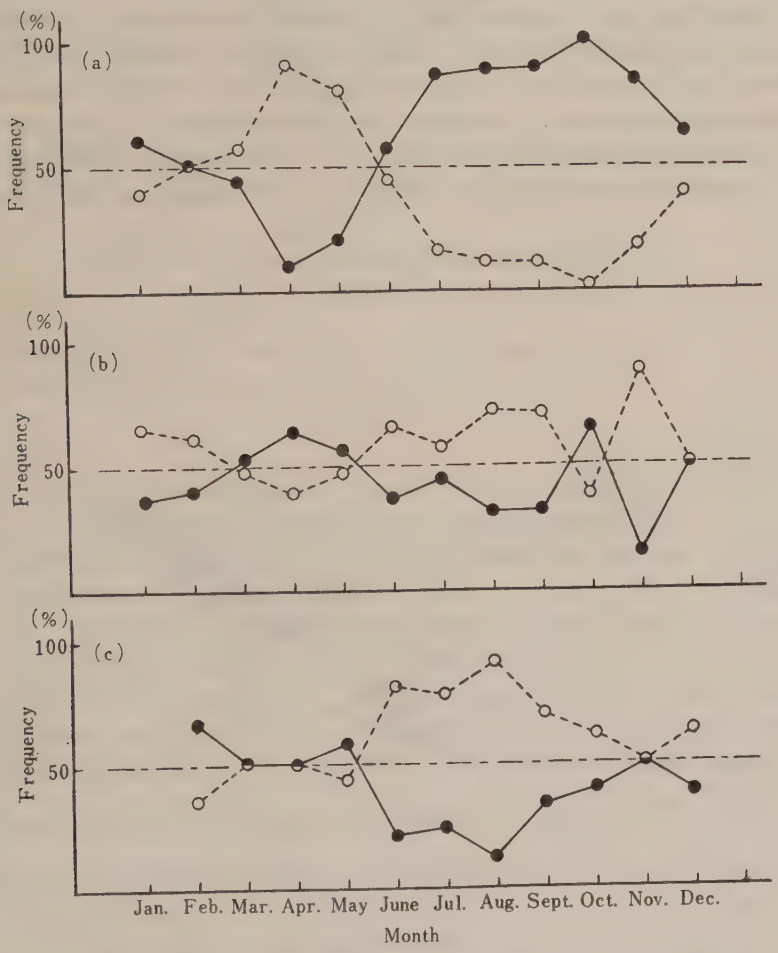

Fig. 3. Monthly change of relative frequency of *v*- and *V*-groups.
a: Small sized (white-bait) group, under 50 mm. in body length.
b: Medium sized group, 50 mm.—100 mm. in body length.
c: Large sized group, over 100 mm. in body length.

Note: ● ..... *v*-group
○ ..... *V*-group

from autumn one. In both medium and large size groups, the seasonal alternation of *V*- and *v*-group is inapparent (Figs. 3b and 3c), probably because these two groups mingle with each other either during the development or during fishing and even among the catch.

2. Marks formed on scale

Although no marks are distinctly formed both on otolith and on centrum, these are always found on scale. Among the scales taken throughout the lateral side of the same fish, there are found three types: (1) scales of bilateral symmetry is A-type, being provided with marks formed well; (2) asymmetrical scale, though resembling much A-type scale in general appearence, is B-type where marks are less distinctly formed and (3) scale of irregular form is C-type where marks are nearly always inrecognizable and any definite measuring axis cannot be chosen adequately. Hereafter, A-type scales only are used for reading. A-type scales, after taken off from fish, are soaked in 3% KOH solution for about 15 hours for cleaning, then washed well with water and put between two

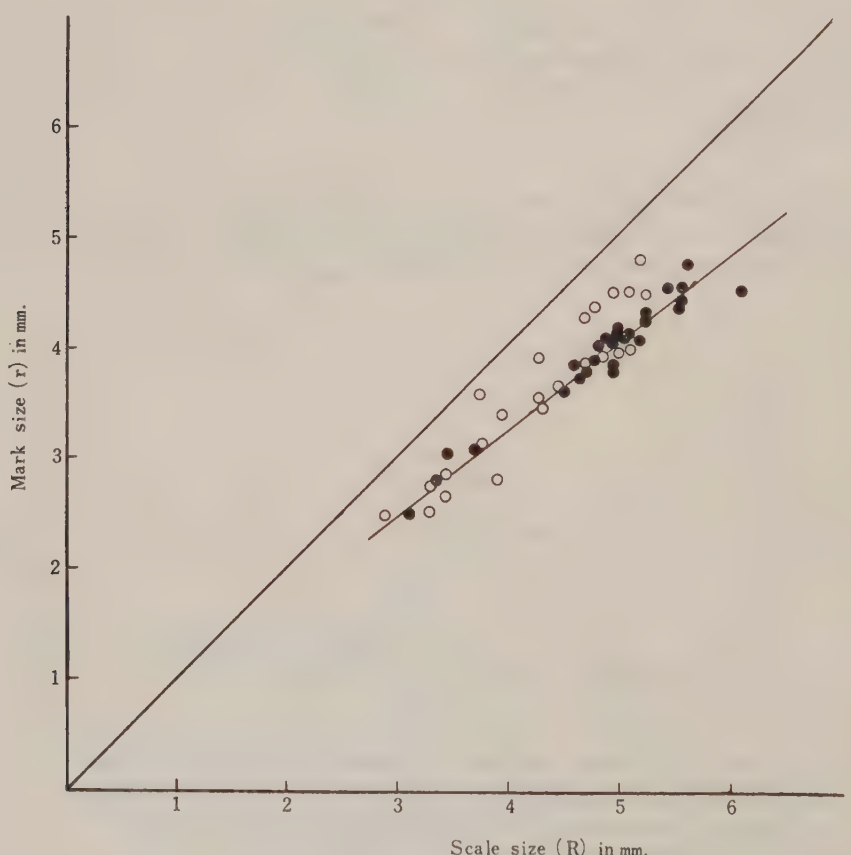

Fig. 4a. Similarity of mark size within the same fish (S_1).
Note: ● .... A-type scale, ○ .... B-type scale

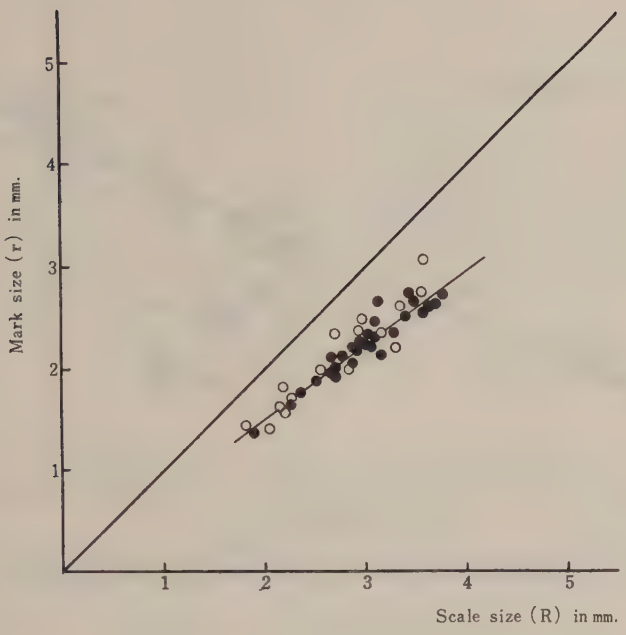

Fig. 4b. Similarity of mark size within the same fish (s_1).
Note: ● .... A-type scale, ○ .... B-type scale

slide glasses. The scales prepared in this way are enlarged by twenty times by the projector made by the Nippon Kogaku Co. and measured.

2.1 Type of the mark: Scales of the Japanese anchovy are of inflection-type and marks are defined as cutting-over made of ridges (Menon, 1950; Allen et al, 1956), (Plate. I). Scale size, R in mm., and mark size, r in mm., are measured along the antero-lateral axis (Plates. I and II).

2.2 Similarity of mark size: The relationship of scale size with mark size is approximately expressed by a straight line (Figs. 4a and 4b), indicating that there exists similarity of mark size. Here, any measured mark size, r, can be standardized by such a procedure as $\hat{r}=r\cdot\frac{\hat{R}}{R}$, where $\hat{r}$ is standardized mark size and $\hat{R}$ is known from relationship between body length, L, and scale size, R, $\hat{R}=0.0433\ \mathrm{L}-1.16$ (Fig. 5).
Hereafter, our discussion is made based on the standardized mark size.

2.3 Correspondency of mark size: The frequency distribution curve of the innermost mark (Fig. 6) is composed of two modal groups, one of these modes is situated in the range between 2.25 mm. and 2.75 mm. ($s_1$mark), another is in that between 3.75 mm. and 4.00 mm. (S_1-mark) respectively. Similarly the frequency distribution of the marks succeeding the innermost one shows also two modes, one between 3.75 mm. and 4.25 mm. (s_2-mark) and another between

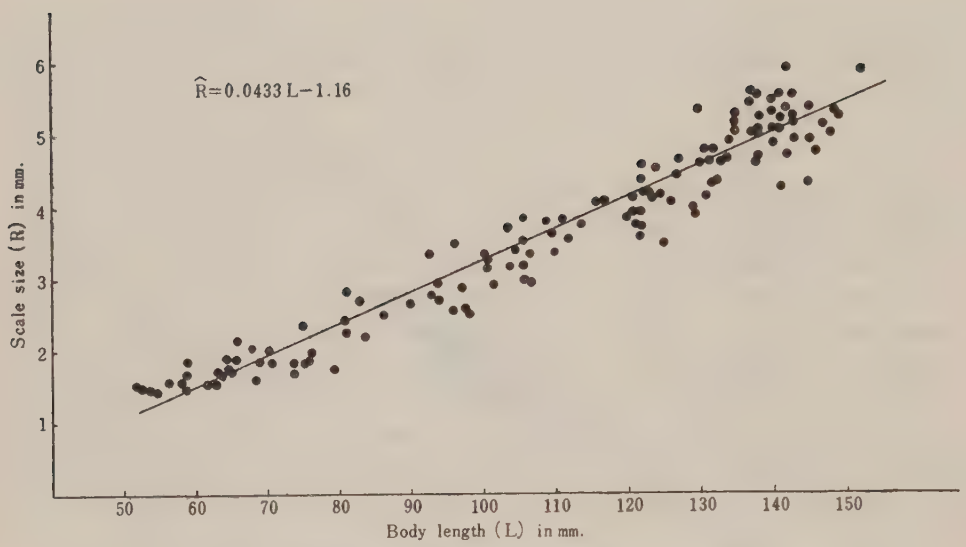

Fig. 5. Relationship between body length and scale size.

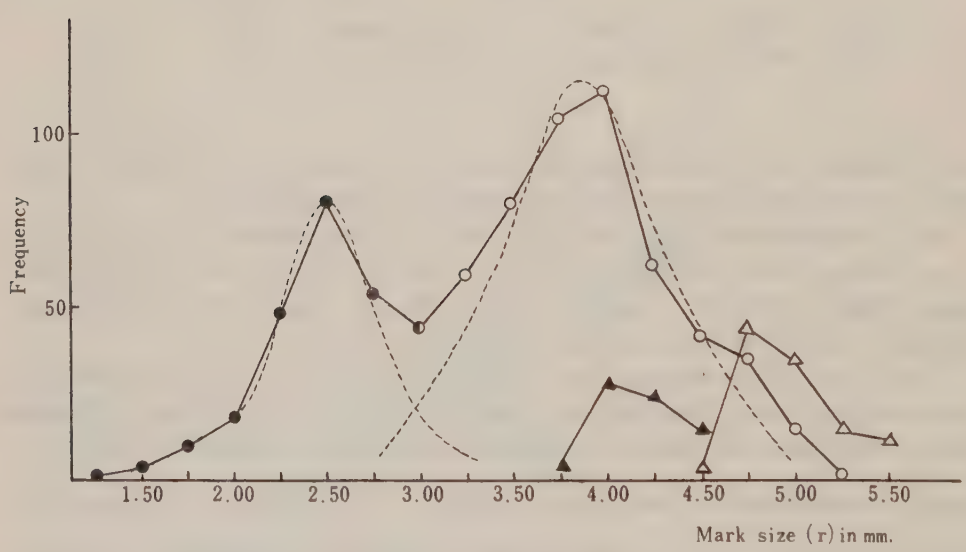

Fig. 6. Frequency distribution of mark size.
Note: ● .... s_1-group, ▲ .... S_1-group
○ .... s_2-group, △ .... S_2-group

4.75 mm. and 5.00 mm. (S_2-mark) (Fig. 6). Two-mark scale is either of $s_1.s_2$- or of $S_1.S_2$-type, but neither of $s_1.S_2$- nor of $S_1.s_2$-type (Fig. 7). The relationship of body length with mark size, though approximately, is expressed by a straight line with the variation within the confidence interval (Pr. 90%), indicating

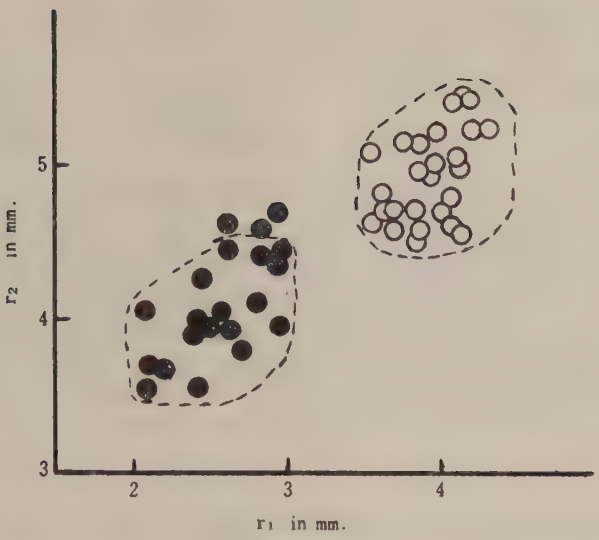

Fig. 7. Relationship between the innermost mark size (r_1) and the succeeding one (r_2).

Note: ● .... $s_1.s_2$-group, ○ .... $S_1.S_2$-group

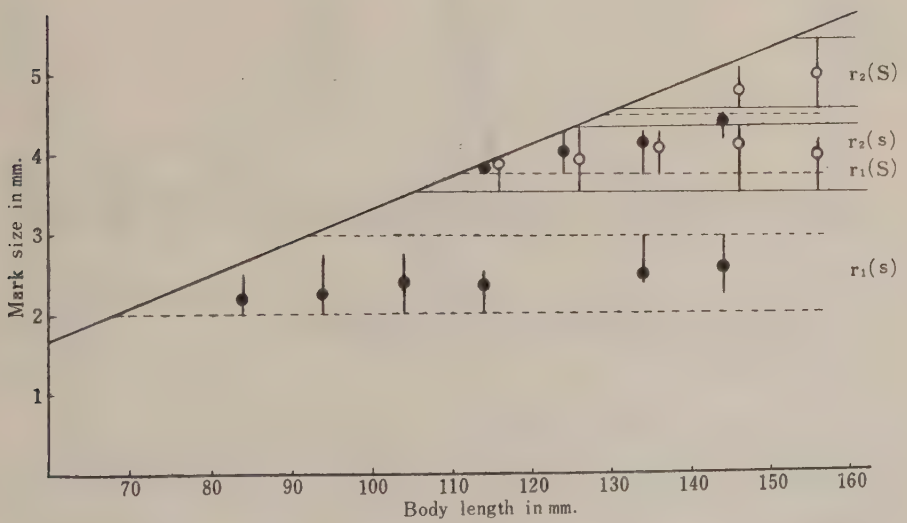

Fig. 8. Correspondency of mark size in each size class.

Note: ● .... s-group, ○ .... S-group

that correspondency is recognized in mark size throughout a wide range of body length and also that mark size remains nearly constant (Fig. 8).

By substituting the maximum and minimum estimates of the mark size, intermediate body length in mm. with its deviation is computed as below.

(unit: mm.)

$r_1(s)$	$r_2(s)$	$l_1(s)$	$l_2(s)$
2.00～2.95	3.75～4.50	69.5～93.5	112.1～129.1
$r_1(S)$	$r_2(S)$	$l_1(S)$	$l_2(S)$
3.50～4.34	4.55～5.45	106.4～125.9	130.5～151.1

2.4 Time when mark is formed: The relative frequency of individuals with scales which have first mark along its margine changes monthly in both *s*- and *S*-groups (Fig. 9). This frequency attains maximum in December and January, showing that the marks (s_1 and S_1) are formed during these months. The second mark (s_2 and S_2) must be similarly formed in these same months, even though based on insufficient data. In other words, all the marks are formed in winter.

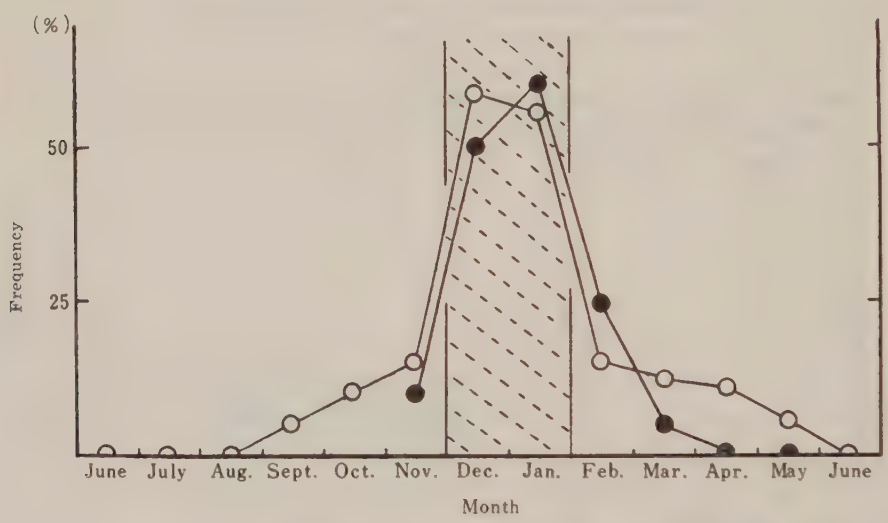

Fig. 9. Monthly change in relative frequency of individuals with scale which has the first mark along its margine.
Note: ● .... s_1-group, ○ .... S_1-group

Table 1. Probability of mark formation in each fish.

Group	S_1					S_2				
Specimen number	I	II	III	IV	mean	I	II	III	IV	mean
Number of scale read	20	20	20	18	20	20	20	19	19	20
Number of scale with mark	20	17	16	16	17	19	18	19	15	18
Pr.	1	.85	.80	.89	.85	.95	.90	1	.79	.90

2.5 The probability of mark formation: The probability of mark-formation is generally high in each fish (Table 1), and also in group, being 0.84 (92 fishes among 110) between 70 mm. and 130 mm. in body length in March when the first mark must be present on scale.

3. Discrimination of race based on the first mark size

As stated before, two groups are distinguished from each other based on the types of first mark (s_1 and S_1). The variation type in vertebral number, so far as S_1-group is concerned, is generally of V-type (percentage frequency of individuals with vertebral number more than 45 is significantly higher than that with less than 45). On the other hand, s_1-group is always of v-type (percentage frequency of individuals with vertebral number less than 45 is significantly higher than that more than 45 or the difference between both rather insignificant) (Table 2). Whereas, S-group is considered as originated from spring brood group and s-group from autumn one.

Table 2. Variation-types of vertebral number with the different mark-types.

Region (Locality)	*S*-group						*s*-group					
	Variation					Type (average)	Variation					Type (average)
	43	44	45	46	47		43	44	45	46	47	
Nankai		12	58	**29**		V (45.17)	1	7	13	11		v (45.09)
Seikai	1	2	18	**13**		V (45.27)		**9**	16	2		v (44.74)
Naikai							2	**21**	37	8		v (44.78)
Japan Sea (Kyoto)		2	15	**9**	1	V (45.33)		2	4	3	1	.....
Tokai		1	10	**10**	3	V (45.62)	2	8	10	3		v (44.62)
Tohoku (Aomori)		4	15	**12**	1	V (45.31)		9	9	8	1	v (45.04)
Hokkaido		6	30	**19**	1	V (45.27)			5			.....

Note: Gothic letters indicate the significant dominacy to characterize the group.

Aikawa (1950, '54), *Yokota* et *Furukawa* (1952), *Asami* et *Hanaoka* (1957), after discriminating races based on the vertebral number, traced the growth course and attained nearly similar estimates. The body length at the end of year given by these authors just coincides intermediate body length, when the mark is formed, that is, $l_1(s)$ from $r_1(s)$, $l_2(s)$ from $r_2(s)$, $l_1(S)$ from $r_1(S)$ and $l_2(S)$ from $r_2(S)$ respectively. Large sized individuals with three marks or more (2.5 or nearly 3 years or older) are never found among the catch from the coastal waters.

Lastly it must be noted here that the intermediate body length $l_1(s)$ is smallest and that while $l_1(S) < l_2(s) < l_2(S)$, all the differences between them are

very slight. The autumn brood will grow more rapidly than the spring brood after the former passes its first winter.

4. **Analysis with the fallen scales**

As it is difficult to take scales directly from fish of this species, because they fall easily during fishing, and after landing the catch bulk of scales is always left in the hold of boat, it is rather advantageous to use the fallen scales for the age-determination and racial analysis.

From the catch off Fukuoka in April 1957, scales of bucketful were sampled from four different part in the hold of boat, after mixed altogether, about 1300 scales are taken and among them A-type scales only are used for measurement, as they are least variable in several respects.

Unimodal frequency distribution of scale size well coincides with that of body length and there is no significant difference between them (Fig. 10). The

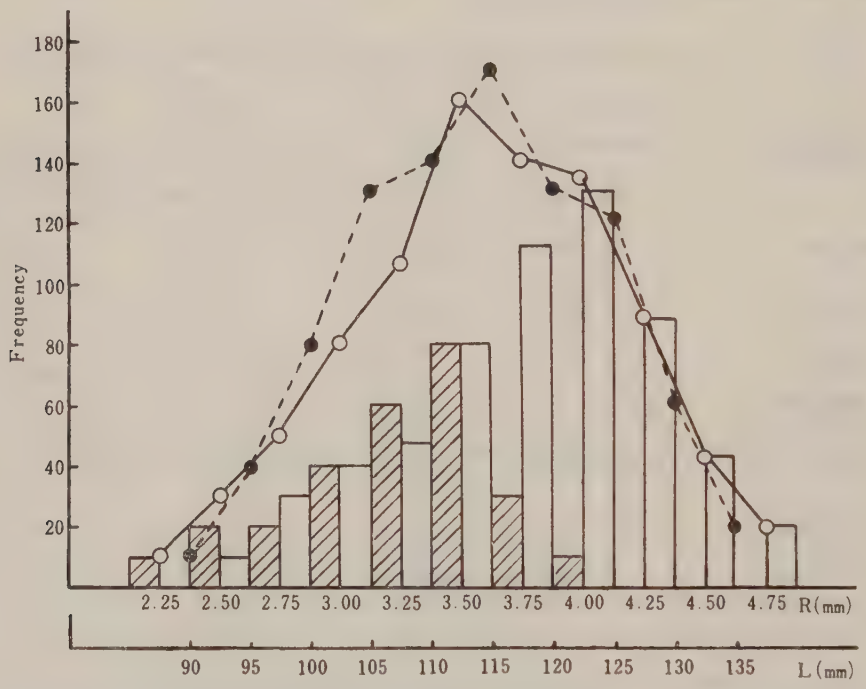

Fig. 10. Frequency distribution curve of the body length from the catch and of size of the fallen scale left after landing.

Note: ● .... Frequency of body length, *L*.
○ .... Frequency of scale size, *R*.
Histograms .... Scales with s_1-mark (shaded), and with S_1-mark (open).

relationship between scale size, *R*, and mark size, *r*, though there is no scales with two marks, is expressed by two straight lines (Fig. 11). Accordingly among this material there must be two groups such as S_1 and s_1 both mingling with each

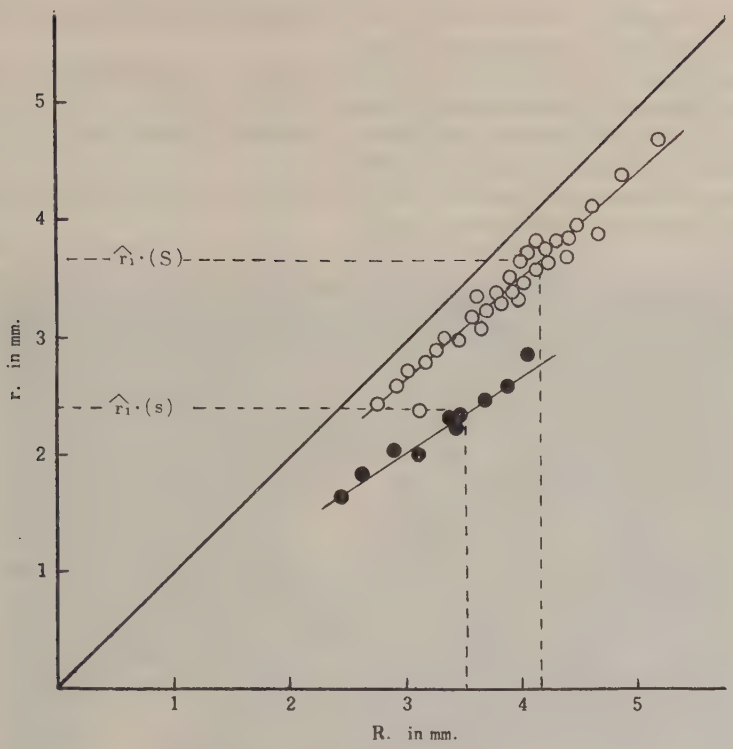

Fig. 11. Similarity of mark size in the fallen scales.
Note: ● .... s_1-group, ○ .... S_1-group

other. Based on the ratio of S_1 or s_1, in each size class, the total group can be divided into those of S_1 and s_1 respectively. Taking these modal values as standard mark size, r_1, they are 2.40 mm. for s_1-group and 3.68 mm. for S_1-group. These estimates equal those obtained from scales taken directly from fish. By the same way, two-mark group can be divided, when the composition of scales with different type of mark is known, into two different groups such as $s_1.s_2$- and $S_1.S_2$-groups.

Lastly, based on the scale composition, any group can be qualitatively discriminated either as a race-complex or as a single race and also analyzed quantitatively into different races whenever it is composed of both spring and autumn broods.

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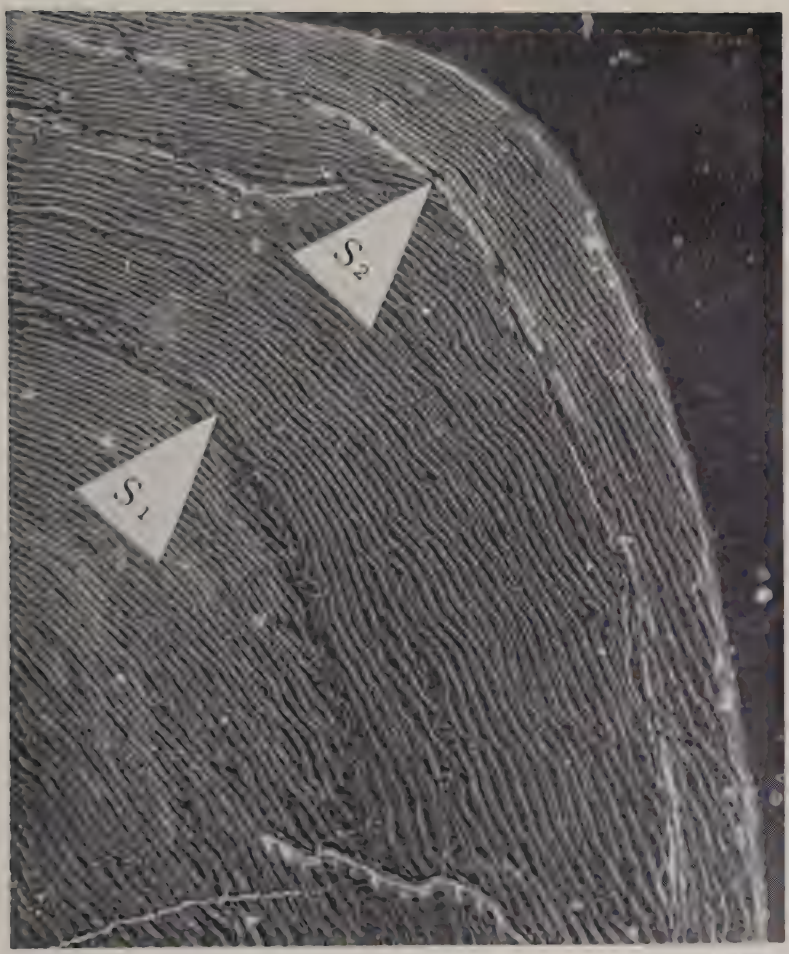

Plate I.
Antero-lateral side of marks formed on scale (*S*-group).

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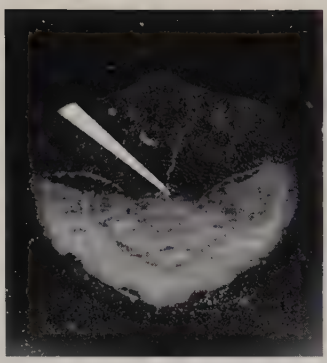
Plate II.

Antero-lateral side of marks formed on scale (*s*-group).

(a) × 9



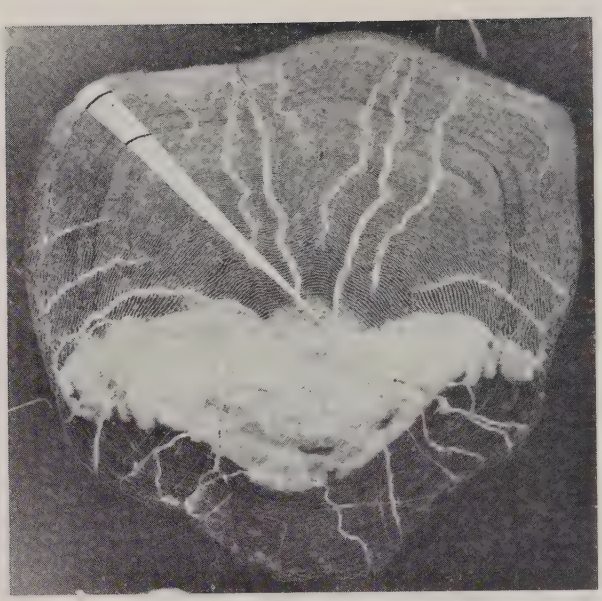
(b) × 9

(c) × 8

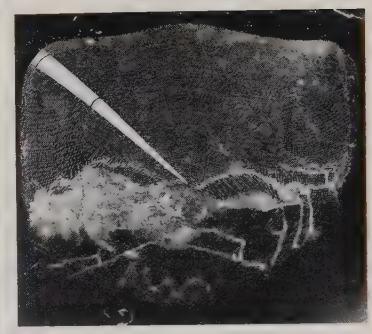
(d) × 8

Plate III.

(a) Scale from fish 76 mm., caught in July. No mark presents.
(b) Scale from fish 61 mm., caught in December. No mark presents.
(c) Scale from fish 134 mm., caught in April. S_1-mark presents.
(d) Scale from fish 89 mm., caught in April. s_1-mark presents.



(e) × 8



(f) × 5.5

Plate III.—continued

(e) Scale from fish 156 mm., caught in July. S_1- and S_2-mark present.

(f) Scale from fish 123 mm., caught in January. s_1- and s_2-mark present.

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in Japan. (Special Number 3)
October 1959

THE MARINE ALGAE OF THE KII PENINSULA

By the collections of the marine algae at several places of the Kii Peninsula the following species were newly added to the list of the marine flora of this region.

By
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Rhodophyceae

Protoflorideae
Goniotrichum alsidii HOWE
Florideae
Nemalionales
Trichogloea lubrica J. AGARDH
Cryptonemiales
Chondrococcus japonicus OKAMURA
Gigartinales
Gelidiopsis variabilis SCHMITZ
Ceramiales
Ceramium aduncum NAKAMURA
Carpoblepharis erecta YAMADA
Crouania minutissima YAMADA
Microcladia corallinae OKAMURA
Rhodochorton codii NAKAMURA
Spyridia filamentosa HARVEY
Pleonosporium sp.
Polysiphonia aggregata SEGI

Phaeophyceae

Isogeneratae
Ectocarpales
Ectocarpus izuensis SEGAWA
Heterogeneratae
Laminariales
Eckloniopsis radicosa OKAMURA
Ecklonia kurome OKAMURA
Ecklonia kurome f. *contorta* OKAMURA

Cyclosporae

Fucales

Sargassum alternato-pinnatum YAMADA

Sargassum thunbergii O. KUNTZE

Chlorophyceae

Siphonales

Codium lucasii SETCHELL

Codium pugniformis OKAMURA

One noteworthy alga among the above listed species is *Crouania minutissima* YAMADA which was found from Koza, Prov. Kii. Originally this species was described basing on the specimen from the Caroline Islands in 1944. Since then it has been reported also from the Marshall Islands, Formosa and Ryukyu archipelago. Therefore it is evident that by the finding of this species at Koza we could add a new tropical elenment to the flora of this region.

Another species which must be taken into consideration in connection with the distribution is *Gelidiopsis variabilis* SCHMITZ which was reported from Shirahama, Kii Prov. Relating to the study of *Gelidiopsis variabilis* SCHM. several points regarding to this genus were elucidated.

The genus Gelidiopsis was established by F. SCHMITZ in 1895 when he studied the marine algae from East Africa and noticed that *Gelidium pannosum* GRUNOW was quite different anatomically from true *Gelidium*. As the type species of the new genus he assigned *Gelidiopsis variabilis* (GREVILLE) SCHMITZ which had been described by GREVILLE as *Gigartina variabilis* GREV. (Cf. ENGLER's Bot. Jahrb. 1895, p. 148). At the same time *Gelidium scoparium* MONT. et MILL. and *Gelidium repens* KUETZ. were removed into *Gelidiopsis* by SCHMITZ. After that VICKERS also removed *Acrocarpus gracilis* KG., *Acrocarpus intricatus* KG. and *Sphaerococcus intricatus* C. AG. to *Gelidiopsis* (Liste des algues mar. de la Barbade, 1905), and SETCHELL and GARDNER described *Gelidiopsis tenuis* from the Gulf of California in 1924. But that is FELDMANN who elucidated almost all the species so far described and especially the systematic relation between *Gelidiopsis* and *Gelidium* on one hand, and *Echinocaulon* on the other basing upon the precise studies of their authentic specimens. Because it seems to be very rare case to find cystocarps in any species of this genus we must rely upon other characteristics for distinguishing this genus from allied genera and therefore it is quite natural that the difference in the anatomical characters of the frond plays most important role.

In his Nippon Kaisoshi (Marine algae of Japan) OKAMURA enumerates two species of *Gelidiopsis* from Japan; *G. repens* SCHM. from Formosa, Ryukyu and Seto, Kii Prov. and *G. variabilis* SCHM. from Hoapinsu, Ryukyu (KUROIWA and HEYDRICH), but he does not seem to have had any specimens of the latter species, because in his herbarium there is only one specimen under *G. repens*

SCHM. from Kotosho, Formosa. Afterward the writer collected *G. intricate* VICKERS and *G. gracilis* VICKERS beside *G. repens* SCHM. and *G. variabilis* SCHM. from Formosa and Ryukyu, and he described *G. hachijoensis* YAMADA et SEGAWA from the Island of Hachijo. Therefore to our present knowledge, there are known five species of *Gelidiopsis* from the Japanese coast and Formosa, all representing the tropical or at least subtropical species.

In connection with this genus also the following fact may be mentioned here. In his work, "Some marine algae from Mauritius, Additions to the parts previously published, VI, 1954", BOERGESEN reported *Gelidiopsis scoparia* (MONT. et MILL.) SCHMITZ giving a nice photograph of his specimen. The writer also have had several opportunities to meet across with the same specimens as this in several places of Formosa, and it does not seem to him to be referred to *G. scoparia* SCHM. but *G. repens* SCHM. Thanks to the kindness of Prof. ROGER HEIM and Dr. P. BOURRELLY the writer had an opportunity to see the type specimen of MONTAGNE in the Herbarium of the Muséum National d'Histoire Naturelle in Paris, and could confirm the above mentioned conclusion. The specimens of MONTAGNE of this species are mounted on one sheet being kept in four small envelopes, and the very characteristic scoparious branchlets are found in rather few specimens. Therefore for the writer it is very difficult to determine whether these peculiar branchlets are the normal ones for this species or represent only abnormal ones. If the case would be the latter one, *G. scoparia* SCHM. may be very nearly related to *G. variabilis* SCHM. or representing merely a form of this species. At any rate the Mauritian specimens referred to this species by BOERGESEN is nothing to do with *G. scoparia* (MONT. et MILL.) SCHM.

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STUDIES ON THE CORALLINACEOUS ALGAE IN THE WARMER SEAS AROUND JAPAN

By

Sokichi Segawa

(Fisheries Laboratory, Faculty of Agriculture, Kyushu University)

1. Investigation of the coralline algal flora of the Kii Peninsula.

The survey of the coralline algal flora was carried out again at Kada, Shirahama, Shio-no-misaki, Ooshima and Taiji in Wakayama Pref., and Wagu in Mié Pref., in August, 1957.

As the survey was made at the growing season of many coralline algae, the outcome was much expected. The species collected were, however, nearly same in number as those of the last year. It is concluded, therefore, that the flora of these algae is not so rich in these districts.

2. Comparative anatomy of unarticulated corallines.

In the course of the comparative anatomy of unarticulated corallines using the materials collected from Hachijô Island, Miyake Island, Kii Peninsula and other southern parts of Japan, the following results have been obtained.

(A) Systematic position of the genus *Mastophora*.

According to KYLIN (1956), the genus *Mastophora* is reserved in the group of "Ungenügend bekannte Corallinaceen". The examinations using the materials of *Mastophora rosea* collected from Hachijô Island and other localities, made clear the following respects.

(a) *Mastophora rosea* can be properly referred to the *Lithophyllum* group, because the tetrasporangial conceptacle is conical in shape, and has a single opening (Fig. 1).

(b) This species is very closely related to the genus *Metamastophora*, because the development of tetrasporangial and male conceptacles well coincides with that of *Metamastophora lamourouxii* (DECAISNE) SETCHELL studied by SUNESON (1945).

(c) This species differs from *Lithophyllum* in that the former forms a thick lenticular fusion-cell after fertilization. Although SUNESON did not observe the female organ of *Metamastophora*, it is supposed that this peculiarity in the fusion-cell is also true in the genus *Metamastophora*.

(d) It seems that the difference of vegetative structure between *Mastophora* and *Metamastophora* lies in that the former has trichocyte and rhizoidal cell.

(B) Systematic position of the genus *Lithoporella*.

The genus *Lithoporella* is also placed by KYLIN (1956) in the same group as the genus *Mastophora*.

After anatomical observations on the materials collected from Hachijô Island and other localities, *Lithoporella* sp. almost concurs with the genus *Mastophora* in their vegetative structure, three sorts of conceptacles, and other characters. The author, therefore, came to the conclusion that these two genera should be stand near each other, in spite of the difference of their outer appearance.

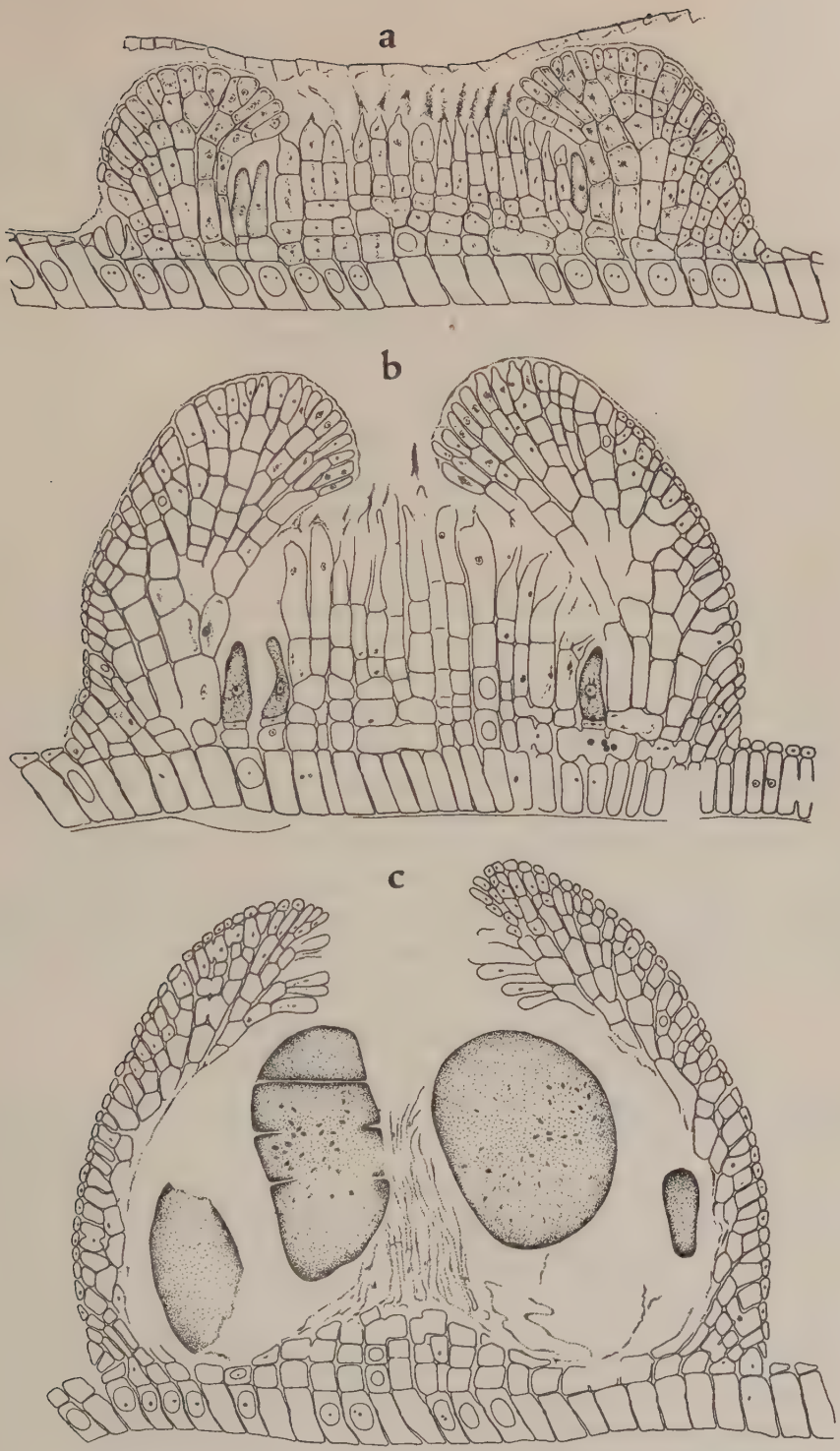

Fig. 1. *Mastophora rosea.* Sections of the tetrasporangial conceptacle. (× 110)

a. early stage.
b. more advanced stage.
c. mature conceptacle.

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ON THE PRESENCE OF AT LEAST TWO SPECIES OF *CUBICEPS* (*NOMEIDAE, PISCES*) IN THE PATH OF THE "KURO-SHIWO"

By
Tokiharu Abe

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During the fiscal year 1957 (April 1, 1957–March 31, 1958), the writer made trips* to Shikoku, Kii Peninsula and Sagami Bay devoting special attention to the annual fluctuation in the course and strength of the "Kuro-shiwo" and to the annual changes in the elements of the piscifauna of these parts of Japan which are directly in the path of this current. Among the fishes gathered from these waters are two small specimens of *Cubiceps pauciradiatus* GÜNTHER which is believed new to Japanese fauna. Specimens of the young of *Cubiceps gracilis* LOWE are also included in the collection, and a few adult examples of this commercial species were observed at the Central Wholesale Market of Tokyo as in previous fiscal years (*cf.* ABE, 1955). It is thought timely to give account of *Cubiceps pauciradiatus* and suggest that the fishes previously recorded from Japanese waters as *Mulichthys squamiceps* LLOYD and *Cubiceps natalensis* GILCHRIST & VON BONDE may be the young of *Cubiceps gracilis*.

Cubiceps pauciradiatus GÜNTHER
"Hoso-okimedai" (New Japanese Name)

Cubiceps pauciradiatus GÜNTHER 1872, p. 432. Misol Island (Mollucas Is.). 5 ⅔ inches long. ————————REGAN, 1902, pp. 123 & 124. Misol. 120 mm in total length. Probably the type.

Description of a example (Cat. No. ABE '57–347) from Sagami Bay. Taken by a trap net off Manazuru (western coast of Sagami Bay) during December 15, 1957–January 10, 1958. Preserved in strong alcohol. Total length *ca.* 150 mm, fork length 132 mm, standard length 120 mm.

Proportional measurements. The following measurements are given in hundredths of the standard length: Greatest depth of body (at origin of 1st dorsal fin) 25.0, greatest breadth of body (near hind end of head) 14.2, least depth of caudal peduncle 9.3, length of head 30.4 (left) and 29.2 (right), horizontal diameter of eye 9.0 (left) and *ca.* 9.3, vertical diameter of eye 8.8 (left)

* Aided by a grant-in-aid from the Japanese National Commission for Unesco. The writer expresses here his sincere thanks to the commission and Mr. B. ARAYA (Japanese Association for the Promotion of Science) for their courtesy.

and 8.7 (right), length of snout 8.6 (left) and 8.3 (right), bony interorbital breadth (above eye-centers) 9.9, length of longest (5th; tips of 3rd and 4th spines damaged) spine of 1st dorsal fin 11.9, length of longest (5th; 2nd to 4th fin-rays damaged distally) soft fin-ray of 2nd dorsal 8.3, length of 2nd anal spine *ca.* 3.3 (1st anal spine very short), length of longest soft fin-ray of anal 10.0, length of longest (4th from top on either side) fin-ray of pectoral 3.5 on either side, length of ventral spine 8.8 (left) and 7.3 (right), length of longest (1st and 2nd counted from outside on left side, though tips damaged slightly; 2nd on right side, 1st being damaged distally) soft fin-rays of ventral 12.1 (left) and 11.7 (right), length of longest (uppermost of lower limb) gill-raker on right 1st arch 3.5

General appearance, and color in alcohol. The body is rather long, compressed posteriorly, and weakly keeled in front of the ventral origins. The ventral fins originate distinctly behind the postero-ventral ends of the pectoral bases, and are received in a very narrow triangular depression which is pointed posteriorly and ends far in advance of the anal origin. The posterior tips of the ventral fins reach only midway between the ventral origins and the anal origin. The pectoral fins are distinctly longer than the head, the posterior tips reaching the vertical through the anterior end of the vent (when the fins oppressed horizontally). The humeral plate on either side is well developed, and the scales behind each pectoral base seem to be larger than the other scales. The caudal fin is deeply forked. The interorbital area is scaled, broad, and slightly convex. There is a longitudinal, extremely narrow depression (or, rather a line) along the mid-drosal line of the head, originating above anterior half of the eyes and terminating above the anterior fourth of the operculum on either side. The bony ridge above the eye on either side is very pronounced. The snout is very slightly shorter than the eye, and not rounded (unlike *Cubiceps gracilis*). The maxillary on either side is mostly hidden beneath the preorbital, and extends nearly to the vertical through the anterior margin of the eye.

The lateral line on either side is placed very high. A line running along the middle of the flank resembles the lateral line of many ordinary fishes; the former is believed to be the main longitudinal mucous canal. As the scales have mostly been rubbed off, mucous pores can hardly be seen on the trunk. In each pocket receiving a scale are found reticulations which are believed to be the branches of mucous canals. The mucous pores can easily be seen with the aid of lens on the snout. The nostrils are paired on either side, very small, and placed much nearer to the snout tip than to the front margin of the eye on either side.

The color in alcohol is balckish above, and silvery below; especially the lower jaw, subocular part of the head and the larger scales behind the pectoral base on either side shine conspicuously. The anterior part of the abdomen (probably the scales having been rubbed off) shows very conspicuous canals and minute reticulations connecting them, and is whitish (bearing brownish or violet tint).

Fin-formulae. D. XI (1st spine very short), 18 (=ii+16; 1st ray spine-like). A. II 16 (=i+15). P. 19 (=ii+*ca.* 17). V. I 5 (all soft-rays branched) on either side. C. 8/7 (branched fin-rays only have been counted).

Scales. As stated above, the scales have mostly been rubbed off, and those which remain behind the pectoral base and those near the origin of the lateral line on either side are all cycloid. The number of the scales along the lateral line is difficult to count because of the shrinkage of the skin of the posterior part of the body. The pockets receiving scales are fairly large. The following numbers of scales are those of the pockets. The number of the scales in an oblique row passing the origin of the 1st dorsal fin down obliquely backward to the scale just above the lateral line is ½ 2 on either side. The number of the scale longitudinal rows counted from the one just below the lateral line down to the scale row just above the median, lateral-line-like canal is 2 below the origin of the 1st dorsal fin; 3 below the middle of this fin; 4 below the junction of the 1st and 2nd dorsal fins. The number of the vertical (though oblique) scale rows passing the median lateral-line-like canal is *ca.* 45 on either side. The number of the scales along the lateral line counted from the anterior end of the line back to the one just below the hindmost dorsal spine is *ca.* 19 on either side. The number of the scales in an oblique row passing the anal origin up and forward to the scale just below the median lateral-line-like canal is 7 on either side, and from the one just above this canal to the one at the base of the anterior part of the 2nd dorsal fin is ½ 6 (left) and 7(right).

Gills, pseudobranchiae, gill-rakers and branchiostegals. Gills 4; a slit behind the 4th gill, provided with rakers along anterior and posterior margins. Pseudobranchiae very well developed. Gill-rakers moderately strong and long, numbering 10+16 on the right side. The left branchiostegal membrane very slightly laps over the right. The number of the branchiostegals on the right side is 6.

The lining of the branchial cavity is black.

Teeth, tongue, and skin-folds of buccal cavity. Though covered by whitish mucus, the lining of the buccal cavity and the skin-folds above and below forming a pocket inside of the upper or lower jaw are all balck. The teeth are present on the jaws, vomer, tongue and probably very few on palatines. The jaw teeth are small, rather slender, arranged mostly in a single series, and covered basally by a continuous semi-transparent membrane on each jaw. The longitudinal tooth band of the vomer is attenuated anteriorly. The tooth band of the tongue is elliptical, and fairly broad. The palatines seem to be provided with only a few teeth.

The tongue is broad, slightly concave above, and braodly rounded anteriorly.

Notes on another example (Cat. No. KAMOHARA 6759=tentative no. ABE 10832) from Kochi Prefecture, Shikoku. This specimen is in a bad state, the left side of the trunk and head having been injured. It was collected by Dr. T. KAMOHARA in Kochi Prefecture probably early in 1957, and has been placed

at the present writer's disposal, although it will be returned to Dr. KAMOHARA because of its rareness there. The present writer wishes to express his sincere thanks to Dr. KAMOHARA for his cordial cooperation.

The specimen measures ca. 87 mm in fork length, and 80 mm in standard length. The following measurements are given in hundredths of the standard length: Greatest depth of body (at poseterior end of preventral keel) 22.3, greatest breadth of body (at anterior part of operculum) 10.0, least depth of caudal peduncle 7.9, length of head 27.5 (right side only), horizontal diameter of eye 8.8 (right), vertical diameter of eye 8.1 (right), length of snout 6.6 (right), bony interoribtal breadth (above eye-centers) 7.1, length of longest (4th and 5th) dorsal spines 12.3, length of longest (3rd; counting the 1st short unbranched fin-ray which is believed to have been lost) soft fin-ray of 2nd dorsal 10.0, length of longest (2nd) soft fin-ray of anal 8.8, length of longest (4th and 5th counted from top on either side) fin-ray of pectoral 27.5 (left) and 26.9 (right), length of longest (outermost 2) fin-rays of ventral 12.5 on either side.

D. XII (1st spine extremely short) i (presumed to have existed; a small pit probably receiving the fin-ray remains) 17 (=i+16; anteriomost unbranched fin-ray fairly long). A. I (very short) 17 (=i+16). P. 19 (=ii+*ca.* 17) on either side. V. 15 (all soft fin-rays branched) on either side. The total number of vertebrae is *ca.* 31 (examined by X-rays).

The body is rather long and fairly compressed. The pectoral fins are nearly as long as the head.

The preventral keel is conspicuous. The ventral fins are received in a groove as in the other specimen described above. The ventral origins are distinctly behind the vertical through the postero-ventral ends of the pectoral bases. The posterior tips of the ventral fins reach very slightly beyond midway between ventral and anal origins.

The scales have been rubbed off, and the skin has shrunk. The lateral line is high in position; approximately 2 scale rows above it. The color in formalin is grey, the dorsal and caudal fins, operculum and snout being blackish. The lining of the branchial cavity is black on either side, but the tongue and the lining of the buccal cavity are partly light colored.

The inner fold of the left branchiostegal membrane slightly laps over the right. The number of the branchiostegals can not be counted. Gills 4; a slit behind the 4th. Number of gill-rakers 8+1+16 on either side.

The teeth are present on jaws, vomer and palatines. The teeth of the lower jaw are rather slender, covered basally by a semi-transparent continuous membrane, and number *ca.* 30 (left) and 32 (right). The teeth of the upper jaw are similar in shape to those of the lower jaw, and number *ca.* 26 (counting smaller teeth) (left) and *ca.* 22 (right). The jaw teeth are slightly curved inward. The vomerine teeth are arranged in a longitudinal band which tapers anteriorily. The palatine teeth are very few in number. The teeth of the tongue are arranged in a whitish longitudinal band which tapers posteriorly. The skinny fold inside of the

upper jaw and that of the lower jaw are well developed. The tongue is broad, the anterior margin being nearly vertical to the longitudinal axis of body.

The pair of the lateral sacs of the posterior part of the pharynx are circular in outline when seen from side. The distance between the anterior ends of the sacs is smaller than the distance between the posterior ends of the sacs.

As shown above, *Cubiceps pauciradiatus* differs considerably from *C. gracilis* (*cf.* ABE, 1955). It is now evident that at least two species of the genus *Cubiceps* occur in the path of the "Kuro-shiwo". There still remains some doubt as to the identity of *Atimostoma capense* SMITH, (1845) 1849, with *gracilis*, and the writer wishes to collect specimens of adults of *pauciradiatus*.

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TURBIDITY DISTRIBUTION IN THE SUBARCTIC WATER OF THE NORTH PACIFIC IN THE SUMMER OF 1957

By

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(Faculty of Fisheries, Hokkaido University)

Introduction

Since the first trial manufacture of a turbidity meter in 1954 (M. Fukuda, N. Inoue and S. Nishizawa, 1954), observations of turbidity were made in the Bering Sea in 1955 and 1956 (M. Fukuda and N. Inoue, in preparation). In the late summer of 1956, turbidity distribution in the East China Sea was observed using a newly designed turbidity meter of simple structure (S. Nishizawa and N. Inoue, 1958). The authors noticed from the results of these observations that the turbidity of sea water was a very useful criterion for the identification of a water mass, the relation between turbidity and depth of a water mass being kept fairly constant in a given season. They especially found out that near the layer in which a sudden increase of water density occurred there was always found a corresponding turbidity increase or decrease, often accompanied with a sharp and thin sheet of maximum or minimum turbidity. Nishizawa and Inoue also discussed the relation of vertical turbidity distribution to the production of phyto-plankton population in a shallow homogeneous water mass, and sometimes found that the vertical gradient of turbidity changes with depth almost parallel to the estimated phyto-plankton production. The downward transport of suspended material was also calculated from the observed vertical distribution of turbidity and it was noticed that the transport increased down to the bottom of the euphotic layer whilst below that it did not increase but often decreased gradually.

From the end of August to the middle of September 1957, the present authors took charge of a part of the oceanographic observation, aiming at the polar front survey in the North Pacific as a part of the I.G.Y. program, on board the Oshoro Maru; they had opportunities to suspend a turbidity meter down to 100 m or so in the region of the Subarctic water of the North Pacific. The informations regarding turbidity distribution obtained in this cruise were rather fragmentary and the fine structure of the polar front area could not be clarified satisfactorily but some characteristic properties of the water in this region could be seen from the following description of observations.

The authors thank the captain and crew of the Oshoro Maru for their kind help in the tedious work at sea during the cruise.

Instrument

The detailed explanation of the turbidity meter used in the present observation has already been given in the previous paper (S. Nishizawa and N. Inoue, 1958); here some improvements made previous to the cruise will be described.

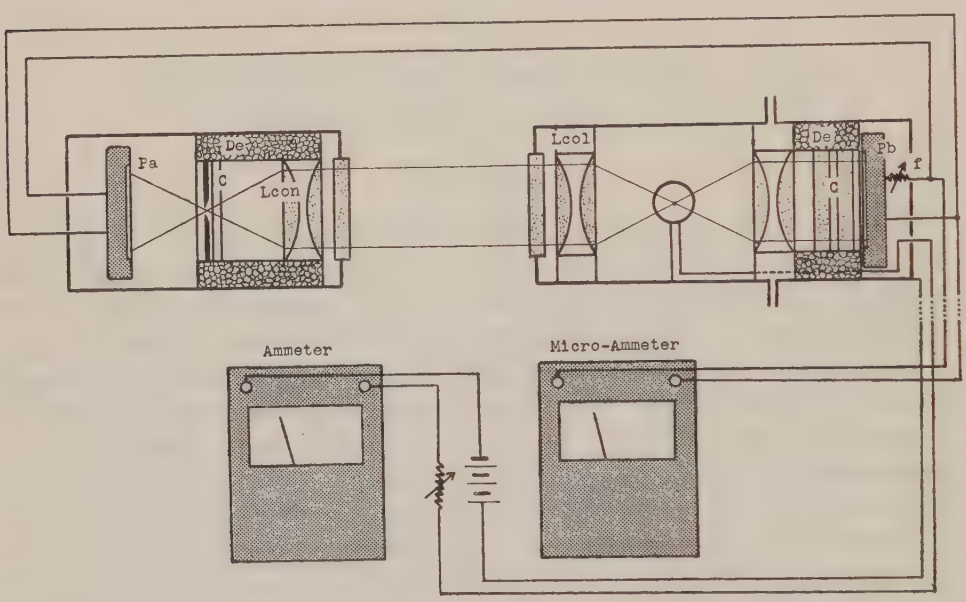

Fig. 1. The optical system of the turbidity meter and the measuring circuit. L: Tungusten lamp; Pa: Working photocell; Pb: Compensating photocell; Lcol: Collimating lens; Lcon: Condenser lens; De: Desiccant agent; C: Color filter; f: Variable resistor.

To gain temperature balance of two photocells, light receiving cell and compensating one, a small electric heater of equivalent wattage to the light source lamp had been inserted in the light receiving chamber, but it was rejected in the present observation; between the lamp and the compensating cell were set up a collimating lens and two sheets of glass just the same as in the measuring light pass as shown in Fig. 1. These enable the compensating photocell to get the same amount of light as the light receiving photocell when the whole instrument was placed in air. Heat transference from the lamp to the compensating cell was prevented satisfactorily by the two glass sheets. The photocell circuit was altered by arranging two cells under short circuit condition, which made it possible to set a color filter (its center of gravity of transmission 532 mμ) in front of the light receiving photocell without reducing the measuring accuracy compared to the previous circuit.

To secure a higher stability of measuring circuit, a variable resistor f which could be adjusted from outside at any time before hanging was inserted in the compensating circuit. It was adjusted so as to bring about no deflection of the microammeter A during some variation of the lamp current near the regular value (1.25 A) when the instrument was placed in air. All this was easily arranged but the balance was broken off easily as well, so it was necessary to adjust the resistor before every hanging down of the instrument into water.

Before hanging down, a 90% neutral density filter was inserted into the light pass and the lamp current was adjusted and fixed so as to bring about a definite deflection of the microammeter; this was done without destroying the zero point balancing when the resistor f was carefully adjusted beforehand.

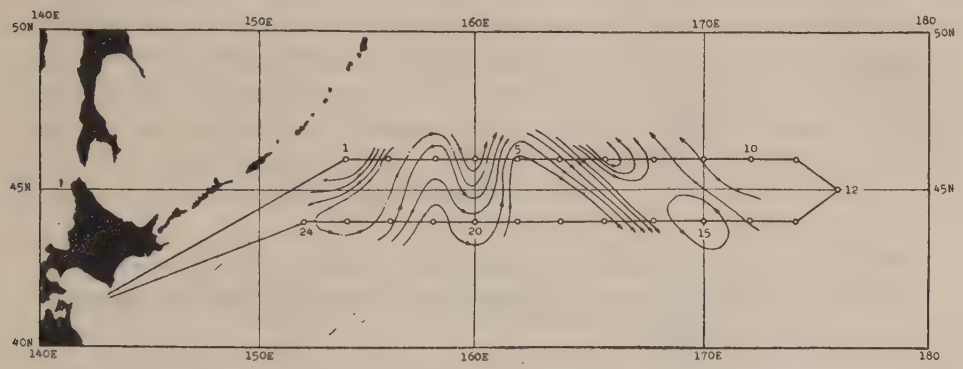

Fig. 2. Positions of stations occupied in the observation cruise of the Oshoro Maru from August 23 to September 13, 1957. Turbidity observation was carried out only on the returning course along the line of 44°N. Dynamic topography referred to 800 decibar surface is also inserted.

Results of Observation

The positions of hydrographic stations occupied in the present cruise are shown in Fig. 2. The dynamic topography of the sea surface referred to 800 decibar surface is also drawn in the same figure. Turbidity observation was carried out only on the returning course along the 44°N line. In Figs. 3 to 9 are shown vertical distributions of turbidity and temperature at several stations. The whole section of turbidity is illustrated in Fig. 10 in which temperature and chlorinity distributions are also drawn for comparison.

Turbidity values are expressed in per cent ratio of the amount of light which is transmitted through the water of 50 cm light pass and reached to the light receiving photocell to that amount received by the same photocell when the light pass was occupied by clear air. When the instrument is dipped in water the reflection of the incident light at the surfaces of the two window glasses disappears and the turbidity values expressed in the above manner often exceed 100% in clear water.

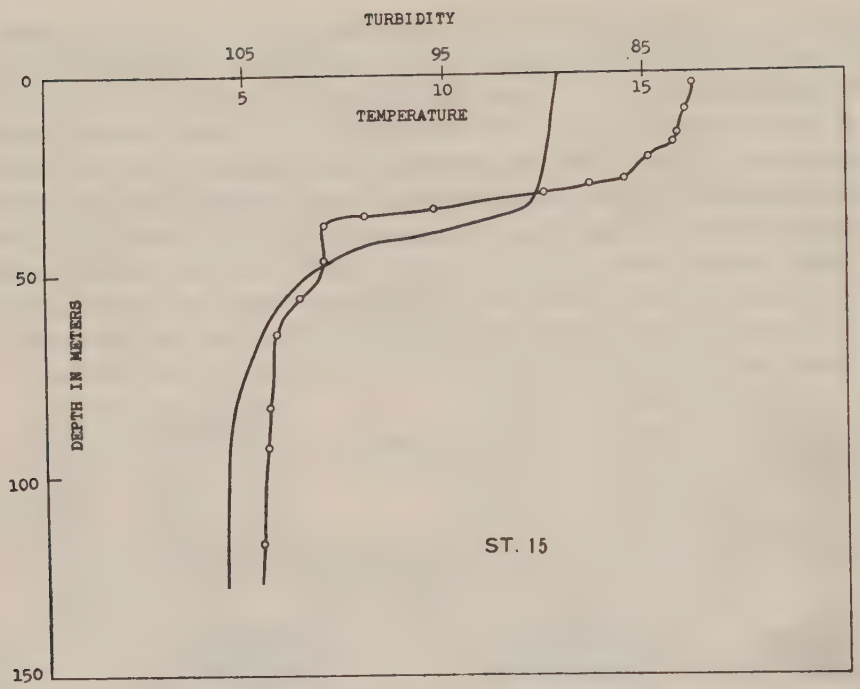

Fig. 3. Vertical distributions of turbidity (line through circles) and temperature at station 15.

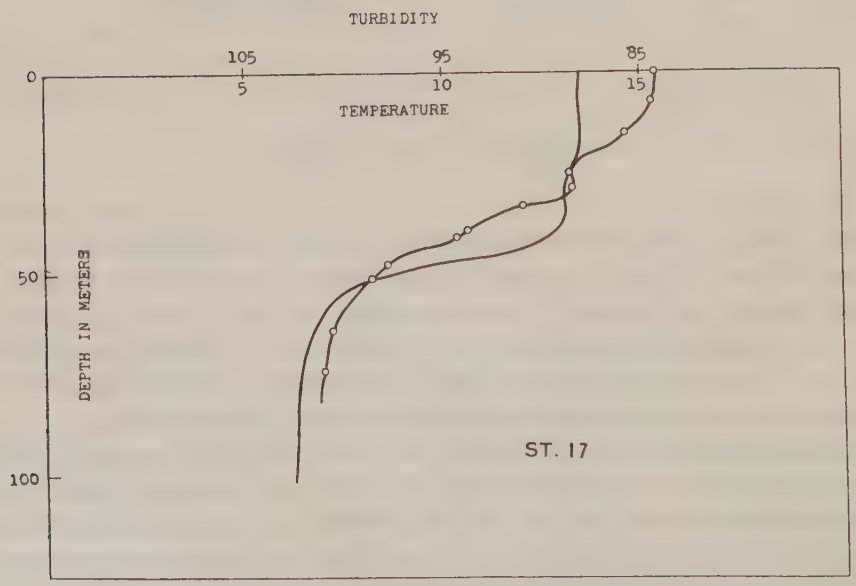

Fig. 4. Vertical distributions of turbidity (line through circles) and temperature at station 17.

(a) *Vertical distributions of turbidity* (cf. Figs. 3 to 9). It is seen from the temperature distribution that the convection layer in this district has a thickness of about 20 to 40 m, and the thermocline at the bottom of the convection layer is very sharp, temperature jump in it ranging 7 to 10°C. In the convection layer the turbidity is nearly uniform down to the thermocline and there it decreases suddenly following a course nearly parallel with the temperature. Below the thermocline the turbidity decreases gradually with a course strictly parallel to temperature. It is very striking that the thermocline lays out a firm barrier against the downward transport of the suspended material. Most of the suspended particles will linger in the convection layer being prevented from falling further by the sharp thermocline underlying and being agitated vigorously there. They will thus decompose in the convection layer and a small part of them will sink down below the thermocline. Between station 17 and 19 where a northward movement of the rather warm water is found the temperature jumps at the thermocline are smaller than at other stations and the turbidity change at the thermocline is also less sharp; at station 19 its vertical distribution is of double step variation and at station 17 the downward decrease of turbidity is fairly gradual through the thermocline.

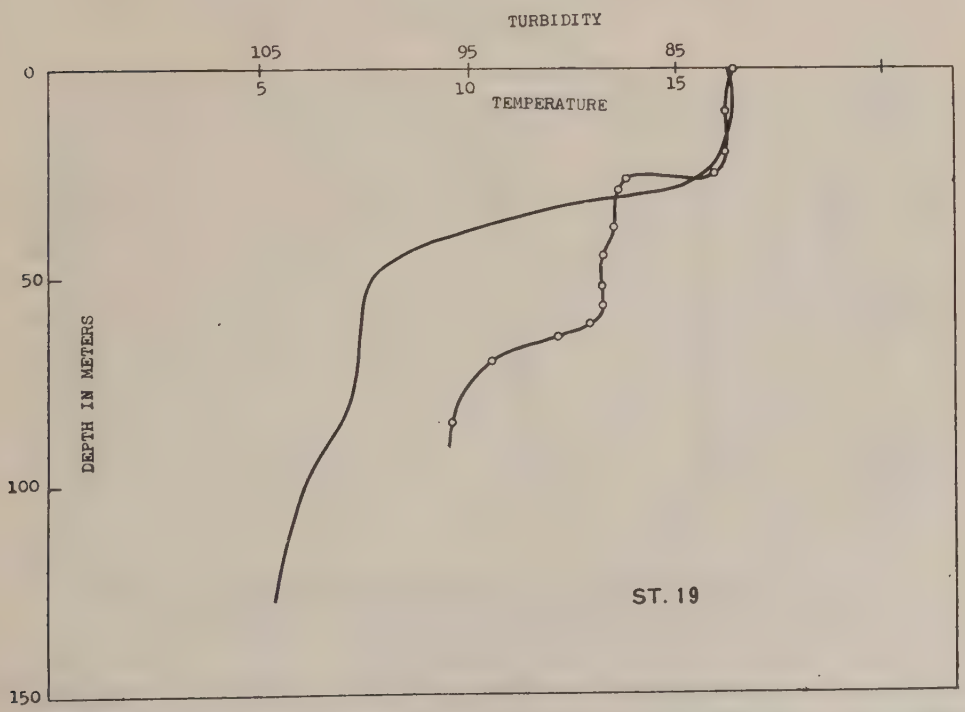

Fig. 5. Vertical distributions of turbidity (line through circles) and temperature at station 19.

At station 22, where an extremely clear water exists, a remarkable maximum of turbidity is found at the layer of thermocline. A middepth maximum of turbidity has often been found in the homogeneous shallow water near the bottom of the euphotic layer of phyto-plankton (S. Nishizawa and N. Inoue, 1958); this is mainly due to the large production of phyto-plankton in the middepth. But the maximum at this station is probably caused by the horizontal diffusion of the turbid water of the neighbouring water mass along the surface of high stability at the thermocline (cf. Fig. 10). A small maximum of turbidity found at the thermocline of station 21 is considered to be of the same nature. In the area covering stations 21 and 22 horizontal contrast of turbidity is greater than in other area (cf. Fig. 10) and horizontal diffusion at the layer of high vertical stability in such area is represented in the distribution of turbidity resulting in the maximum or minimum. Generally speaking, the turbidity contrast in oceanic water is smaller than in coastal water and such a striking middepth peak of turbidity observed on the continental shelf and especially at the edge of it is rarely observed in oceanic water.

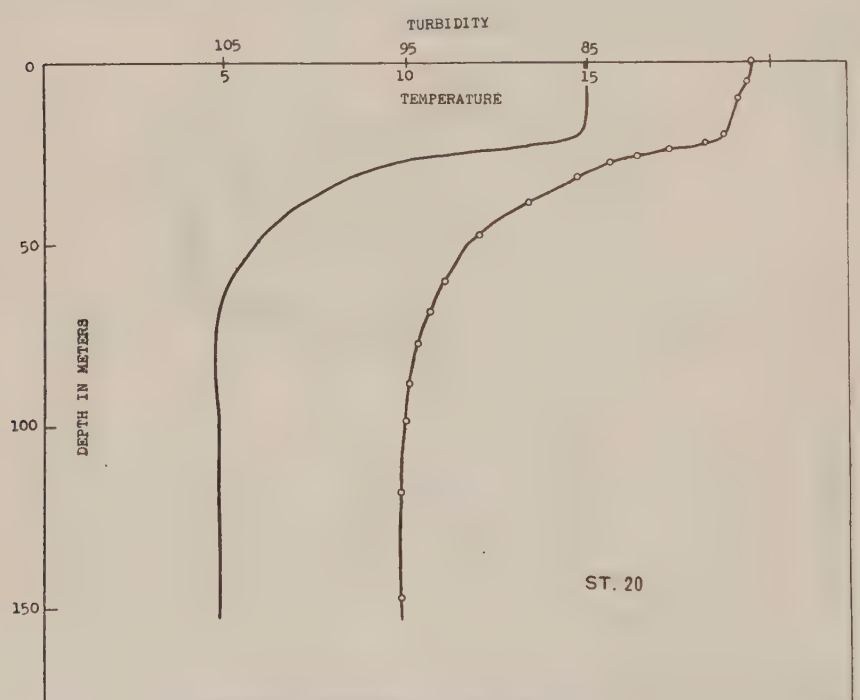

Fig. 6. Vertical distributions of turbidity (line through circles) and temperature at station 20.

(b) *Water mass analysis* (cf. Figs. 2 and 10). At station 1 and 24 the water is very cold and low in chlorinity, having a characteristic T-S relation to the Oyashio. The Oyashio flows south-west in this area. At stations 15 to 19

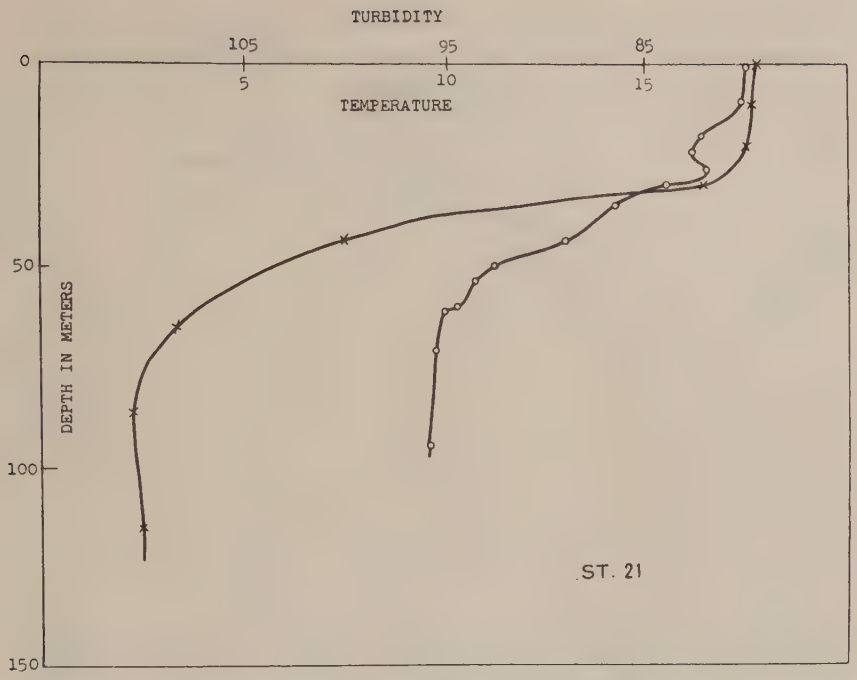

Fig. 7. Vertical distributions of turbidity (line through circles) and temperature at station 21.

a northward extrusion of the Subarctic water is encountered. The Oyashio does not come in contact directly with the Subarctic water in this region, but a narrow band of cold water which forms an eddy of counter-clockwise circulation lies between them. The water found at stations 2 and 22 is the southern end of this eddy (R. H. Fleming, 1955; S. Mishima and S. Nishizawa 1952; H. Koto, 1958). The area occupied by stations 3, 4, 20 and 21 is on the boundary between the Subarctic water and the cold eddy above mentioned. The warm surface water of the Subarctic water extends over the cold dichothermal layer of the eddy at station 21 and comes up to station 22 in the shallow layer above 30 m. In the eastern part of the present district again a southward flow of the northern water is found and the water decreases in temperature and chlorinity; a temperature minimum found at station 16 at the depth of 100 m is a characteristic property of the water of the eddy above mentioned (S. Mishima and S. Nishizawa, 1952). The general circulation of water in the present district is shown in Fig. 2.

Turbidity distribution in the whole section is shown in Fig. 10. The Oyashio is very turbid especially in the shallow layer, while the counter-clockwise eddy flowing next to it is very clear from the sea surface down to 150 m or so. The middepth maximum of turbidity found in this water at about 30 m depth is considered to be transported horizontally from the adjacent waters as described above. The mixing area between station 21 and 19 is again turbid especially at

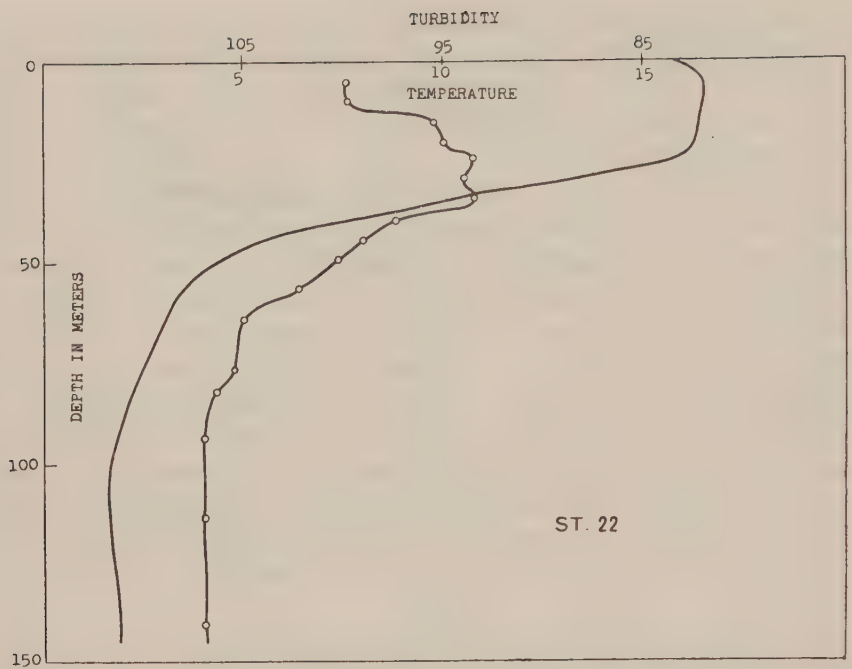

Fig. 8. Vertical distributions of turbidity (line through circles) and temperature at station 22.

the surface. Turbidity of this area below 50 m is also higher than in the adjacent waters as expressed by the turbidity isoplete 95% in Fig. 10. The Subarctic water is rather clear at stations 17 and 18, and in the eastern region where the northern cold water extrudes southward the water becomes again more clear than the Subarctic water proper but a little more turbid than the water found at station 22 which is a predominant component of the northern water.

The high turbidity of mixed water is probably due to high production of phyto-plankton in the polar frontal zone because the two component water masses are less turbid than the mixed water. The surface water at station 16, which is a continuation of the mixed water, is also high in turbidity compared to the neighbouring area but below a depth of 30 m turbidity is nearly the same as in the adjacent water indicating an underwater immersion of the cold water of the eddy which lies in a narrow band to the north of the present region.

It is very interesting to note that high values of turbidity are found in the regions where stability of stratification is also high; the very turbid surface water at station 24 is especially low in chlorinity and the thermocline is also shallow at about 25 m depth. This condition is generally considered to be due to ice-melting along the Kamchatka Peninsula whilst the high temperature of the surface comes from the solar radiation in spring and summer into the highly

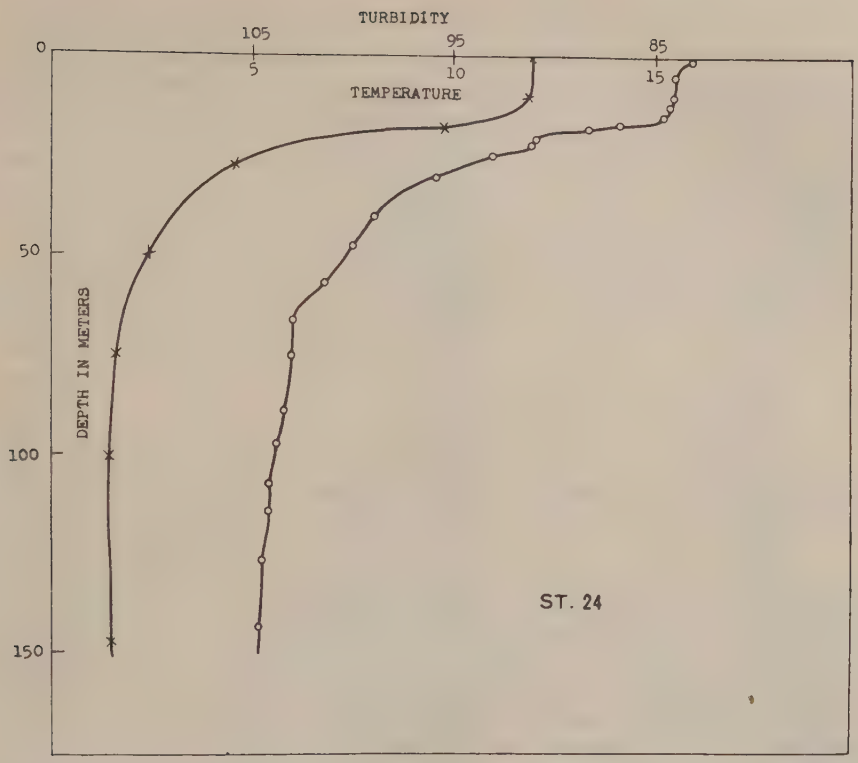

Fig. 9. Vertical distributions of turbidity (line through circles) and temperature at station 24.

stable surface stratification. At station 22, on the other hand, stability in the convection layer is very small; it has received an intense cooling and therefore a vigorous convection process occurs during late winter, resulting in a very unstable surface layer of comparatively high surface chlorinity down to 100 m depth, and hence surface heating in spring and summer transports heated water down to a rather deeper layer than in the Oyashio water. It has, of course, high potential productivity but a low stability may perhaps hamper high production of phyto-plankton (S. Motoda *et al.*, 1955; Y. Kawarada, 1957; K. Karohji, 1958). Many items have been presented by many workers to support the idea that distom production is adversely affected where water is turbulent (for instance, G. A. Riley, 1942; H. U. Sverdrup, 1952). The stability in the mixed area, however, is not very high and it is noticeable that the thermocline in the turbid water found at station 20 is shallow compared to the neighbouring station. It is very interesting that the polar front lies just at station 21 and the surface temperature is highest at the same station but the turbid zone is located on the outer side of the front where surface temperature is rather low.

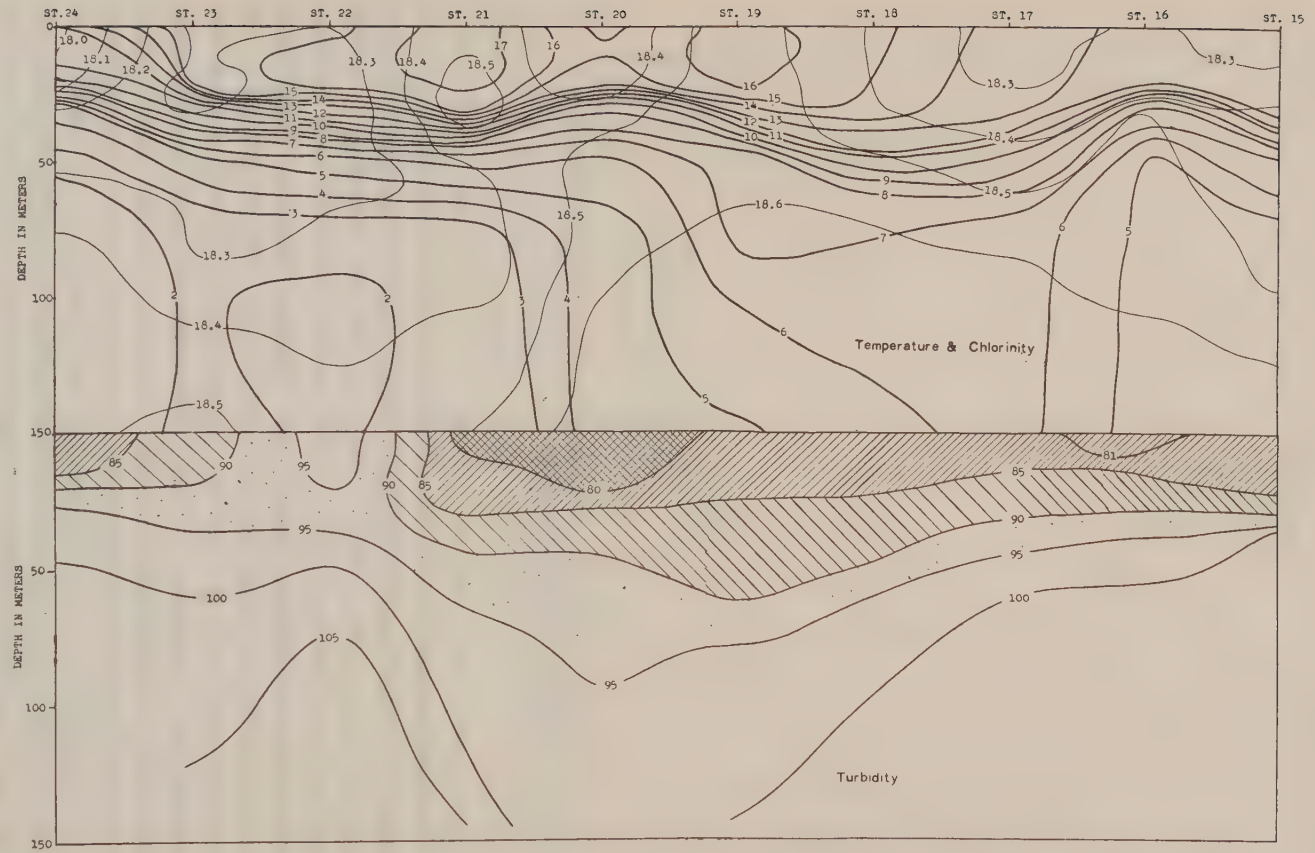

Fig. 10. Distributions of temperature, chlorinity and turbidity at section through stations 15 to 24.

Here an important reservation must be inserted, *viz.*, that the suspended particles which cause an attenuation of the incident light of the turbidity meter are not composed only of living phyto-plankton but also of dead plankton, organic detritus, fecal material and so on. In neritic regions some terrigenous suspended matter such as clay and stirred up bottom sediment must not be overlooked. It is reasonable, however, to assume that the most effective component to turbidity value is planktonic detritus which is finer than living plankton and is suspended in larger quantity than the other components especially in oceanic water. Thus, the turbidity value is considered to depend mainly on living plankton and organic detritus which is also of plankton origin.

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